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DEPARTMENT OF ENERGY

10 CFR Parts 429 and 430

[EERE-2019-BT-TP-0037]

RIN 1904-AE83

Energy Conservation Program: Test Procedure for Consumer Boilers

AGENCY: Office of Energy Efficiency and Renewable Energy, Department of Energy.

ACTION: Final rule.

SUMMARY: The U.S. Department of Energy ("DOE") amends its test procedure for consumer boilers established under the Energy Policy and Conservation Act. This rulemaking fulfills DOE's obligation to review its test procedures for covered products at least once every seven years. The revisions include: incorporating by reference the latest versions of the industry standards currently referenced in the Federal test procedure; relocating the test procedure to a new appendix separate from the residential furnace test procedure; removing an extraneous definition from its regulatory definitions; and making clarifying corrections to calculations. These revisions will improve the representativeness of the test method and will not be unduly burdensome to conduct.

DATES: The effective date of this rule is **[INSERT DATE 30 DAYS AFTER DATE OF PUBLICATION IN THE *FEDERAL REGISTER*]**. The amendments will be mandatory for product testing starting [**INSERT DATE 180 DAYS AFTER DATE OF PUBLICATION IN THE *FEDERAL REGISTER*]**.

The incorporation by reference of certain material listed in the rule is approved by the Director of the Federal Register as of [**INSERT DATE 30 DAYS AFTER DATE OF PUBLICATION IN THE *FEDERAL REGISTER*]**. The incorporation by reference of certain other material listed in the rule was approved by the Director of the Federal Register on March 23, 2009, and February 16, 2016.

ADDRESSES: The docket, which includes *Federal Register* notices, public meeting attendee lists and transcripts, comments, and other supporting documents/materials, is available for review at *www.regulations.gov*. All documents in the docket are listed in the *www.regulations.gov* index. However, not all documents listed in the index may be publicly available, such as those containing information that is exempt from public disclosure.

A link to the docket webpage can be found at *www.regulations.gov/docket/EERE-2019-BT-TP-0037*. The docket webpage contains instructions on how to access all documents, including public comments, in the docket.

For further information on how to review the docket, contact the Appliance and Equipment Standards Program staff at (202) 287-1445 or by email: *ApplianceStandardsQuestions@ee.doe.gov*.

FOR FURTHER INFORMATION CONTACT: Ms. Julia Hegarty, U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Building Technologies Office, EE-2J, 1000 Independence Avenue, SW., Washington, DC, 20585-0121. Telephone: (240) 597-6737. Email: *ApplianceStandardsQuestions@ee.doe.gov*.

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SUPPLEMENTARY INFORMATION: DOE maintains material previously approved for incorporation by reference in part 430: ANSI/ASHRAE 103-1993 and ASTM D2156-09 (Reapproved 2013). DOE incorporates by reference the following industry standards into 10 CFR part 430:

ANSI/ASHRAE Standard 41.6-2014, "Standard Method for Humidity Measurement," ANSI-approved July 3, 2014 ("ASHRAE 41.6-2014").

ANSI/ASHRAE 103-2017, "Method of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnaces and Boilers," ANSI-approved July 3, 2017 ("ASHRAE 103-2017").

Copies of ANSI/ASHRAE 41.6-2014 and ANSI/ASHRAE 103-2017 can be obtained from the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE), 180 Technology Parkway NW, Peachtree Corners, GA 30092, (800) 527-4723 or (404) 636-8400, or online at *www.ashrae.org*.

ASTM International ("ASTM") Standard D2156-09 (Reapproved 2018), "Standard Test Method for Smoke Density in Flue Gases from Burning Distillate Fuels," approved October 1, 2018 ("ASTM D2156-09 (R2018)").

Copies of ASTM D2156-09 (R2018) can be obtained from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959 or online at *www.astm.org*.

International Electrotechnical Commission ("IEC") 62301, "Household electrical appliances—Measurement of standby power," (Edition 2.0) 2011-01 ("IEC 62301").

Copies of IEC 62301 can be obtained from the International Electrotechnical Commission ("IEC"), 3 Rue de Varembe, Case Postale 131, 1211 Geneva 20, Switzerland; or online at *webstore.iec.ch*.

See section IV.N of this document for a further discussion of these standards.

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I. Authority and Background

Furnaces, which include consumer boilers, are included in the list of "covered products" for which the U.S. Department of Energy ("DOE") is authorized to establish and amend energy conservation standards and test procedures. (42 U.S.C. 6291(23); 42 U.S.C. 6292(a)(5)) DOE's energy conservation standards and test procedures for consumer boilers are currently prescribed at 10 CFR 430.32(e)(2) and 10 CFR part 430, subpart B, appendix N, *Uniform Test Method for Measuring the Energy Consumption of Furnaces and Boilers* ("appendix N"), respectively.[1] The following sections discuss DOE's authority to establish test procedures for consumer boilers and relevant background information regarding DOE's consideration of test procedures for this product.

[1] Upon the effective date of this final rule, the test procedure for consumer boilers will be relocated to 10 CFR 430, subpart B, appendix EE.

A. Authority

The Energy Policy and Conservation Act, Pub. L. 94-163, as amended ("EPCA"),[2] authorizes DOE to regulate the energy efficiency of a number of consumer products and certain industrial equipment. (42 U.S.C. 6291–6317) Title III, Part B of EPCA[3] established the Energy Conservation Program for Consumer Products Other Than Automobiles, which sets forth a variety of provisions designed to improve energy efficiency. These products include furnaces, which include consumer boilers, the subject of this document. (42 U.S.C. 6292(a)(5))

The energy conservation program under EPCA consists essentially of four parts: (1) testing, (2) labeling, (3) Federal energy conservation standards, and (4) certification and enforcement procedures. Relevant provisions of EPCA specifically include definitions (42 U.S.C. 6291), test procedures (42 U.S.C. 6293), labeling provisions (42 U.S.C. 6294), energy conservation standards (42 U.S.C. 6295), and the authority to require information and reports from manufacturers (42 U.S.C. 6296).

The testing requirements consist of test procedures that manufacturers of covered products must use as the basis for (1) certifying to DOE that their products comply with the applicable energy conservation standards adopted under EPCA (42 U.S.C. 6295(s)), and (2) making other representations about the efficiency of those products (42 U.S.C. 6293(c)). Similarly, DOE must use these test procedures to determine whether the products comply with any relevant standards promulgated under EPCA. (42 U.S.C. 6295(s))

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[2] All references to EPCA in this document refer to the statute as amended through the Energy Act of 2020, Pub. L. 116-260 (Dec. 27, 2020), which reflect the last statutory amendments that impact Parts A and A-1 of EPCA.

[3] For editorial reasons, upon codification in the U.S. Code, Part B was redesignated Part A.

Federal energy efficiency requirements for covered products established under EPCA generally supersede State laws and regulations concerning energy conservation testing, labeling, and standards. (42 U.S.C. 6297) DOE may, however, grant waivers of Federal preemption for particular State laws or regulations, in accordance with the procedures and other provisions of EPCA. (42 U.S.C. 6297(d))

Under 42 U.S.C. 6293, EPCA sets forth the criteria and procedures DOE must follow when prescribing or amending test procedures for covered products. EPCA requires that any test procedures prescribed or amended under this section shall be reasonably designed to produce test results which measure energy efficiency, energy use, or estimated annual operating cost of a covered product during a representative average use cycle (as determined by the Secretary) or period of use and shall not be unduly burdensome to conduct. (42 U.S.C. 6293(b)(3))

EPCA also requires that, at least once every 7 years, DOE evaluate test procedures for each type of covered product, including consumer boilers, to determine whether amended test procedures would more accurately or fully comply with the requirements for the test procedures to not be unduly burdensome to conduct and be reasonably designed to produce test results that reflect energy efficiency, energy use, and estimated operating costs during a representative average use cycle or period of use. (42 U.S.C. 6293(b)(1)(A))

If the Secretary determines, on her own behalf or in response to a petition by any interested person, that a test procedure should be prescribed or amended, the Secretary shall promptly publish in the *Federal Register* proposed test procedures and afford interested persons an opportunity to present oral and written data, views, and

arguments with respect to such procedures. The comment period on a proposed rule to amend a test procedure shall be at least 60 days and may not exceed 270 days. In prescribing or amending a test procedure, the Secretary shall take into account such information as the Secretary determines relevant to such procedure, including technological developments relating to energy use or energy efficiency of the type (or class) of covered products involved. (42 U.S.C. 6293(b)(2)) If DOE determines that test procedure revisions are not appropriate, DOE must publish its determination not to amend the test procedures.

In addition, EPCA requires that DOE amend its test procedures for all covered products to integrate measures of standby mode and off mode energy consumption into the overall energy efficiency, energy consumption, or other energy descriptor, unless the current test procedure already incorporates the standby mode and off mode energy consumption, or if such integration is technically infeasible. (42 U.S.C. 6295(gg)(2)(A)) If an integrated test procedure is technically infeasible, DOE must prescribe separate standby mode and off mode energy use test procedures for the covered product, if a separate test is technically feasible. (*Id.*) Any such amendment must consider the most current versions of the International Electrotechnical Commission ("IEC") Standard 62301[4] and IEC Standard 62087[5] as applicable. (42 U.S.C. 6295(gg)(2)(A))

DOE is publishing this final rule in satisfaction of the 7-year review requirement specified in EPCA. (42 U.S.C. 6293(b)(1)(A))

[4] IEC 62301, *Household electrical appliances—Measurement of standby power* (Edition 2.0, 2011-01).
[5] IEC 62087, *Audio, video and related equipment—Methods of measurement for power consumption* (Edition 1.0, Parts 1–6: 2015, Part 7: 2018).

B. Background

As stated, DOE's existing test procedure for consumer boilers appears at Title 10 of CFR part 430, subpart B, appendix N, *Uniform Test Method for Measuring the Energy Consumption of Furnaces and Boilers* ("appendix N") and is used to determine the annual fuel utilization efficiency ("AFUE"), which is the regulatory metric for consumer boilers.

DOE most recently updated its test procedure for consumer boilers in a final rule published in the *Federal Register* on January 15, 2016 ("January 2016 Final Rule"). 81 FR 2628. The January 2016 Final Rule amended the existing DOE test procedure for consumer boilers to improve the consistency and accuracy of test results generated using the DOE test procedure and to reduce test burden. In particular, the modifications relevant to consumer boilers included: (1) clarifying the definition of the electrical power term "PE"; (2) adopting a smoke stick test for determining whether minimum default draft factors can be applied; (3) allowing for optional measurement of condensate during establishment of steady-state conditions; (4) updating references to the applicable installation and operation ("I&O") manual and providing clarifications for when the I&O manual does not specify test setup; and (5) revising the AFUE reporting precision. DOE also revised the definitions of several terms in the test procedure and added an enforcement provision to provide a method of test for DOE to determine compliance with the automatic means design requirement mandated by the Energy Independence and Security Act of 2007, Pub. L. 110-140 (Dec. 19, 2007). 81 FR 2628, 2629–2630.

On May 15, 2020, DOE published in the *Federal Register* a request for information ("May 2020 RFI") seeking comments on the existing DOE test procedure for consumer boilers, which incorporates by reference ANSI/ASHRAE Standard 103-1993.

85 FR 29352. ANSI/ASHRAE 103-1993 provides test procedures for determining the AFUE of residential central furnaces and boilers. In the May 2020 RFI, DOE requested comments, information, and data about a number of issues, including: (1) the test procedure's scope and definitions; (2) updates to industry standards; (3) ambient test conditions; (4) provisions for testing boilers with manually adjustable combustion airflow; (5) calculation of steady-state heat loss for condensing, modulating boilers; and (6) provisions for testing step modulating boilers. *Id.* at 85 FR 29354–29357. DOE also sought comment generally on whether the current test procedures are reasonably designed to produce results that measure energy efficiency during a representative average use cycle or period of use, whether any potential amendments would make the test procedure unduly burdensome to conduct, whether existing test procedures limit a manufacturer's ability to provide additional features, the impact of any potential amendments on manufacturers including small businesses, whether there are any potential issues related to emerging smart technologies, and generally any other aspect of the test procedure for consumer boilers. *Id.* at 85 FR 23957.

On March 15, 2022, DOE published in the *Federal Register* a notice of proposed rulemaking ("March 2022 NOPR") proposing to amend the current test procedure to incorporate by reference the most current revision to the applicable industry standard that was available at the time, ANSI/ASHRAE 103-2017, "Methods of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnaces and Boilers," as well as updating the definitions to reflect the changes in ANSI/ASHRAE 103-2017 as compared to the version of the standard currently incorporated by reference (*i.e.*, ANSI/ASHRAE 103-1993). 87 FR 14624. In addition, the March 2022 NOPR proposed to update appendix N to remove the provisions applicable only to consumer boilers and to rename the appendix "Uniform Test Method for Measuring the Energy Consumption of

Furnaces." Correspondingly, DOE proposed to relocate the test procedure specific to consumer boilers at 10 CFR 430 subpart B to a new appendix, EE, "Uniform Test Method for Measuring the Energy Consumption of Boilers" ("appendix EE"). *Id.*

On April 7, 2022, DOE held a public meeting via webinar to solicit feedback from stakeholders on the requests for comment in the March 2022 NOPR.

DOE received comments in response to the March 2022 NOPR from the interested parties listed in Table I.1.

Table I.1 List of Commenters with Written Submission in Response to the March 2022 NOPR

Commenter(s)	Reference in this Final Rule	Comment No. in the Docket	Commenter Type
American Gas Association and American Public Gas Association	AGA and APGA	25	Utility Associations
Air-Conditioning, Heating, and Refrigeration Institute	AHRI	26	Trade Association
A.O. Smith Corporation	A.O. Smith	24	Manufacturer
John Busse	Busse	22	Individual
Bradford White Corporation	BWC	19	Manufacturer
Pacific Gas and Electric Company, San Diego Gas and Electric, and Southern California Edison; (collectively, the California Investor-Owned Utilities)	CA IOUs	20	Utilities
Crown Boiler Company	Crown	16	Manufacturer
Appliance Standards Awareness Project, American Council for an Energy-Efficient Economy, Consumer Federation of America, National Consumer Law Center Natural Resources Defense Council, and Northwest Energy Efficiency Alliance	Joint Advocates	21	Efficiency Organizations
New York State Energy Research and Development Authority	NYSERDA	23	State Agency
Rheem Manufacturing Company	Rheem	18	Manufacturer
U.S. Boiler Company	U.S. Boiler	17	Manufacturer

A parenthetical reference at the end of a comment quotation or paraphrase provides the location of the item in the public record.[6] To the extent that interested parties have provided written comments that are substantively consistent with any oral comments provided during the April 7, 2022, public meeting, DOE cites the written comments throughout this final rule. DOE did not identify any oral comments provided during the webinar that are not substantively addressed by written comments.

II. Synopsis of the Final Rule

In this final rule, DOE updates appendix N to remove the provisions applicable only to consumer boilers and to rename the appendix "Uniform Test Method for Measuring the Energy Consumption of Furnaces." Correspondingly, this final rule establishes a new test procedure specific to consumer boilers in a new appendix EE. In appendix EE, DOE includes all provisions currently included in appendix N relevant to consumer boilers, with the following modifications:

(1) Incorporate by reference the current version of the applicable industry standard, ANSI/ASHRAE 103-2017, "Methods of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnaces and Boilers," which includes several updates to the test method.

[6] The parenthetical reference provides a reference for information located in the docket of DOE's rulemaking to develop test procedures for consumer boilers. (Docket No. EERE-2019-BT-TP-0037, maintained at *www.regulations.gov*.) The references are arranged as follows: (commenter name, comment docket ID number, page of that document).

(2) Incorporate by reference the current version of ASTM Standard D2156-09 (Reapproved 2018), "Standard Test Method for Smoke Density in Flue Gases from Burning Distillate Fuels."

(3) Incorporate by reference ANSI/ASHRAE 41.6-2014, "Standard Method for Humidity Measurement."

(4) Update the definitions to reflect the changes in ANSI/ASHRAE 103-2017 as compared to ANSI/ASHRAE 103-1993.

(5) Provide corrections to erroneous calculations and add clarifications to test conditions and setup requirements.

DOE is also removing the definition of "outdoor furnace or boiler" from 10 CFR 430.2.

The adopted amendments are summarized in Table II.1 compared to the test procedure provision prior to the amendment, as well as the reason for the adopted change.

Table II.1 Summary of Changes in the Amended Test Procedure

DOE Test Procedure Prior to Amendment	Amended Test Procedure	Attribution
Incorporated by reference industry standard ANSI/ASHRAE 103-1993.	Incorporates by reference ANSI/ASHRAE 103-2017 in the new appendix EE.	Harmonization with industry standard update
Incorporated by reference the procedure for adjusting oil-fired burner by referencing industry standard ASTM D2156-09 (Reapproved 2013).	Incorporates by reference the procedure for adjusting oil-fired burner by referencing industry standard ASTM D2156-09 (Reapproved 2018) in the new appendix EE.	Harmonization with industry standard update
Limited the maximum relative humidity of the test room during certain tests but did not provide specific instructions for how to measure relative humidity.	Incorporates by reference ANSI/ASHRAE 41.6-2014 instructions for measuring relative humidity of the test room in the new appendix EE.	Referenced by industry standard ANSI/ASHRAE 103-2017, which is being incorporated by reference in this final rule

DOE Test Procedure Prior to Amendment	Amended Test Procedure	Attribution
Included a definition for "outdoor furnace or boiler" at 10 CFR 430.2.	Removes the definition for "outdoor furnace or boiler"	Unused definition
Included an undefined term, "standard cubic foot of gas."	Adds a definition for "standard cubic foot of gas" in new appendix EE.	Increase clarity for testing conditions
Defined "control" and "isolated combustion system" in appendix N.	Adopts the definitions for the terms "control" and "isolated combustion system" from ASHRAE 103-2017 in new appendix EE.	Harmonization with industry standard update
Referenced calculations in ANSI/ASHRAE 103-1993 which yielded a circular reference when calculating the steady-state efficiency for condensing modulating boilers.	Includes an amended calculation for balance-point temperature (T_C) which resolves the circular reference in new appendix EE.	Correction
Referenced Table 9 in ANSI/ASHRAE 103-1993, which assigned fixed values for the average on-time and off-time per cycle for two-stage and modulating boilers.	References Table 7 of ANSI/ASHRAE 103-2017 in the new appendix EE, which uses calculations for determining the average on-time and off-time per cycle for two-stage and modulating boilers.	Harmonization with industry standard update
Specified cycle times (t_{ON} and t_{OFF}) to a fraction of a second through reference to ANSI/ASHRAE 103-1993 Table 9.	Provides additional specification in appendix EE to require that calculated cycle timings shall be rounded to the nearest second.	Clarification to reduce test burden
Calculated oversize factor from a lookup table based on design heating requirement ("DHR") in ANSI/ASHRAE 103-1993.	Adopts the ANSI/ASHRAE 103-2017 methodology of assigning a constant value of 0.70 to α to represent the national average oversize factor in appendix EE.	Harmonization with industry standard update
Used a purge time limit of 5 seconds to determine whether heat-up and cool-down tests may be optionally omitted, whereas a purge time limit of 30 seconds was used to determine whether a post-purge (t_P) of 0 seconds could be assigned in calculations.	Applies the 30-second limit in appendix EE for determining when the heat-up and cool-down tests may be optionally omitted.	Harmonization with industry standard update
Limited the maximum value of post-purge (t_P) to 180 seconds if a purge time of greater than 3 minutes was observed.	Removes the maximum value of 180 seconds in appendix EE and requires an additional temperature measurement to be taken if the post-purge is greater than 3 minutes.	Harmonization with industry standard update
Referenced calculations for off-cycle infiltration losses in ANSI/ASHRAE 103-1993 which had a typographical error where the conversion from minutes to hours was performed incorrectly.	Specifies the correct calculation for off-cycle infiltration losses through reference to ANSI/ASHRAE 103-2017 and corrects minutes to hours conversion error in new appendix EE.	Correction
Provided inconsistent unit conversion factor from watts ("W") to British thermal units per hour ("Btu/h"), using values of 3.412 or 3.413.	Corrects the conversion factor from W to Btu/h to 3.412 throughout new appendix EE.	Correction
Required the use of a gas having a specific gravity as shown in Table 1 of ANSI/ASHRAE 103-1993.	Requires the use of a gas having a specific gravity "approximate" to what is shown in Table 1 of ANSI/ASHRAE 103-2017 in the new appendix EE.	Clarification to reduce test burden
Referenced incorrect sections of appendix N test procedure regarding average annual auxiliary electrical consumption determination provisions at 10 CFR 430.23(n)(1).	Revises 10 CFR 430.23(n)(1) to update references regarding average annual auxiliary electrical consumption to the correct sections of appendix N and the new appendix EE.	Correction
Referenced values in ANSI/ASHRAE 103-1993 for determining national average burner operating hours ("BOH"), average annual fuel energy consumption ("EF"), and average annual auxiliary electrical energy consumption ("E_{AE}").	References values in ANSI/ASHRAE 103-2017 for determining national average BOH, average annual EF, and average annual E_{AE} in the new appendix EE.	Harmonization with industry standard update

DOE Test Procedure Prior to Amendment	Amended Test Procedure	Attribution
Included instructions for the setup of boilers with draft hoods or draft diverters which specified a minimum R-value for insulation but did not specify the units of measure for R-value.	Includes units of measure for R-value in the new appendix EE.	Correction

DOE has determined that the amendments described in section III of this document and adopted in this final rule will not substantively impact the measured efficiency of consumer boilers or require retesting or recertification solely as a result of DOE's adoption of the amendments to the test procedures. Additionally, DOE has determined that the amendments will not increase the cost of testing. Discussion of DOE's actions is addressed in detail in section III of this document.

The effective date for the amended test procedures adopted in this final rule is 30 days after publication of this document in the *Federal Register*. Representations of energy use or energy efficiency must be based on testing in accordance with the amended test procedures beginning 180 days after the publication of this final rule.

III. Discussion

The subsequent sections of this final rule discuss specific topics raised in this rulemaking, including comments DOE received in response to the March 2022 NOPR. These topics include: scope of applicability of the test procedure, definitions in the test procedure, the AFUE metric, updates to industry standards, clarifications and corrections to the current test procedure, and test conditions.

In addition, DOE received comments relating to the general processes by which DOE amends test procedures and energy conservation standards for covered products and equipment.

BWC urged DOE to consider the cumulative regulatory burden placed on manufacturers that produce several different types of regulated products for which there are simultaneous rulemakings. BWC noted that additional burdens on manufacturers include changes to ENERGY STAR specifications; the Securities and Exchange Commission's proposed rule to enhance and standardize climate-related disclosures; updated state and local codes; demand-response requirements for electric water heaters in Western States; lower nitrogen oxides (NO_X) emissions proposals in the State of California; proposed amendments to California Proposition 65; and extended producer responsibility legislation recently enacted in both Maine and Oregon. (BWC, No. 19 at p. 4-5)

In response, DOE notes that cumulative regulatory burden on manufacturers is assessed as part of energy conservation standards rulemakings. The amendments to the consumer boilers test procedure, as promulgated by this final rule, are not expected to add burden to manufacturers because the amendments do not substantially impact efficiency ratings or alter the type of equipment necessary to perform testing. Test costs and burden are discussed in section III.K of this document.

AGA and APGA commented that DOE should implement the recommendations from the recent National Academies of Sciences, Engineering, and Medicine report ("NASEM report")[7] into all of its appliance rulemakings for test procedures or energy conservation standards. AGA and APGA reiterated recommendations pertaining to analyses that DOE conducts in order to determine whether potential new or amended energy conservation standards are technologically feasible and economically justified.

[7] Although not specified, DOE interprets this comment to refer to the National Academies of Science, Engineering, and Medicine 2021 report entitled "Review of Methods Used by the U.S. Department of Energy in Setting Appliance and Equipment Standards." Copies of the report are available at *nap.nationalacademies.org/catalog/25992/review-of-methods-used-by-the-us-department-of-energy-in-setting-appliance-and-equipment-standards*.

(AGA and APGA, No. 25, p. 3) For example, AGA and APGA highlighted the NASEM report's recommendations that DOE pay greater attention to the justification for its standards, expand the Cost Analysis segment of the Engineering Analysis for its rules, put greater weight on ex post and market-based evidence markups, place greater emphasis on providing an argument for the plausibility and magnitude of any market failure related to the energy efficiency gap, and give greater attention to a broader set of potential market failures on the supply side. *Id*.

Given that this is a test procedure rulemaking for which DOE must meet specific statutory criteria as outlined in 42 U.S.C. 6293(b)(3), the recommendations in the NASEM report which pertain specifically to the processes by which DOE analyzes energy conservation standards are misplaced. DOE will consider this comment in a separate rulemaking considering all product categories.

A. Scope of Applicability

As discussed, in the context of "covered products," EPCA includes boilers in the definition of "furnace." (42 U.S.C. 6291(23)) EPCA defines the term "furnace" to mean a product which utilizes only single-phase electric current, or single-phase electric current or DC current in conjunction with natural gas, propane, or home heating oil, and which: (1) is designed to be the principal heating source for the living space of a residence; (2) is not contained within the same cabinet with a central air conditioner whose rated cooling capacity is above 65,000 Btu/h; (3) is an electric central furnace, electric boiler, forced-air central furnace, gravity central furnace, or low pressure steam or hot water boiler; and (4) has a heat input rate of less than 300,000 Btu/h for electric boilers and low pressure steam or hot water boilers and less than 225,000 Btu/h for forced-air central furnaces, gravity central furnaces, and electric central furnaces. *Id.* DOE has codified this definition in its regulations at 10 CFR 430.2.

DOE defines "electric boiler" as an electrically powered furnace designed to supply low pressure steam or hot water for space heating application. A low pressure steam boiler operates at or below 15 pounds per square inch gauge ("psig") steam pressure; a hot water boiler operates at or below 160 psig water pressure and 250 degrees Fahrenheit (°F) water temperature. 10 CFR 430.2.

DOE defines "low pressure steam or hot water boiler" as an electric, gas or oil burning furnace designed to supply low pressure steam or hot water for space heating application. 10 CFR 430.2. As with an electric boiler, a low pressure steam boiler operates at or below 15 pounds psig steam pressure; a hot water boiler operates at or below 160 psig water pressure and 250 °F water temperature. *Id.*

The scope of the test procedure for consumer boilers is currently specified in section 1 of appendix N, which references section 2 of ANSI/ASHRAE 103-1993. In relevant part, section 2 of ANSI/ASHRAE 103-1993 states that the industry test standard applies to boilers[8] with inputs less than 300,000 Btu/h; having gas, oil, or electric input; and intended for use in residential applications. Further, ANSI/ASHRAE 103-1993 applies to equipment that utilizes single-phase electric current or low-voltage DC current.

DOE is not changing the scope of products covered by its consumer boiler test procedure in this final rule. The following sections discuss specific types of boilers that DOE addressed in the March 2022 NOPR with respect to whether such products are covered by the scope of DOE's test procedure.

[8] ASHRAE 103-1993 defines a boiler as "a self-contained fuel-burning or electrically heated appliance for supplying low pressure steam or hot water for space heating application." This definition covers electric boilers and low pressure steam or hot water boilers as those terms are defined by DOE at 10 CFR 430.2.

1. Combination Space/Water Heating Boilers

Some consumer boilers are capable of providing both space heating and domestic hot water heating, and are often referred to as "combination" boilers. In the March 2022 NOPR, DOE responded to comments from the Northwest Energy Efficiency Alliance ("NEEA") and Rheem recommending that DOE consider developing a separate test procedure for combination space and domestic hot water boilers. 87 FR 14622, 14626–14627. While DOE did not propose a specific definition for combination space and water heating boilers in the NOPR, DOE noted that, to the extent that a combination space and water heating product meets the definition of electric boiler or low pressure steam or hot water boiler, it is subject to the test procedure at appendix N and energy conservation standards for consumer boilers at 10 CFR 430.32(e)(2), and must be tested and rated accordingly. 87 FR 14622, 14625–14626. DOE also stated that it is unaware of any design characteristics of combination space and water heating products that would prevent their testing according to appendix N. *Id.*

DOE did not receive any comments in response to the March 2022 NOPR with regard to combination space and heating water boilers. In this final rule, DOE reiterates its statements presented in the March 2022 NOPR with respect to combination boilers. To the extent that a combination space and water heating product meets the definition of electric boiler or low pressure steam or hot water boiler, it is subject to the test procedure at appendix N (or, as of the effective date of this final rule, appendix EE) and energy conservation standards for consumer boilers at 10 CFR 430.32(e)(2), and must be tested and rated accordingly.

2. Heat Pump Boilers

In the March 2022 NOPR, DOE discussed comments received in response to the May 2021 RFI with regard to hydronic air-to-water and water-to-water heat pumps. DOE tentatively determined that air-to-water and water-to-water heat pumps meet the definitional criteria to be classified as a consumer boiler. 87 FR 14622, 14625. DOE noted that these products utilize only single-phase electric current, are designed to be the principal heating source for the living space of a residence, are not contained within the same cabinet with a central air conditioner whose rated cooling capacity is above 65,000 Btu/h, meet the definition of an electric boiler,[9] and have a heat input rate of less than 300,000 Btu/h (*i.e.*, the requirement for electric boilers). As such, they meet the criteria of "furnace" as defined in 10 CFR 430.2. *Id.* at 87 FR 14625-14626.

In the March 2022 NOPR, DOE also tentatively determined that the test procedure in appendix N does not address such products and would not provide a rated value that is representative of the performance of these products. *Id.* at 14626. In particular, DOE noted that the AFUE metric for electric boilers in ANSI/ASHRAE 103-1993 is calculated as 100 percent minus jacket loss,[10] which provides a representative measure of efficiency for electric boilers using electric resistance technology, for which an efficiency value of 100 percent (the ratio of heat output to energy input) is the maximum upper limit that technically could be achieved. DOE tentatively concluded that the AFUE metric would not provide a representative or meaningful measure of efficiency for a boiler with a heat pump supplying the heat input, because heat pump efficiency (in

[9] "Electric boiler" means an electrically powered furnace designed to supply low pressure steam or hot water for space heating application. A low pressure steam boiler operates at or below 15 psig steam pressure; a hot water boiler operates at or below 160 psig water pressure and 250 °F water temperature. 10 CFR 430.2.

[10] The term "jacket loss" is used by industry to mean the transfer of heat from the outer surface (*i.e.*, jacket) of a boiler to the ambient air surrounding the boiler.

terms of heat output to energy input) typically exceeds 100 percent, and the AFUE metric does not allow for ratings greater than 100 percent for electric boilers. *Id.*

Based on these considerations, DOE tentatively determined that hydronic air-to-water and water-to-water heat pumps are consumer boilers under EPCA, but that due to the lack of a Federal test procedure, such products are not subject to the current performance standards at 10 CFR 430.32(e). *Id.*

In response to the March 2022 NOPR, Crown and U.S. Boiler[11] stated that hydronic heat pumps should not be classified as boilers under EPCA because hydronic heat pumps cannot deliver water at the same temperatures and heating capacities as traditional boilers. Crown and U.S. Boiler further commented that it is unclear whether hydronic heat pumps are "designed to be the principal heating source for a living space of a residence" (a requirement to meet the definition of a furnace at 10 CFR 430.2) because these products are mostly incapable of reaching above 150 °F on a design day, whereas traditional boilers are designed to deliver water at a temperature of 180 °F or higher. Crown and U.S. Boiler also stated that gas, oil, and electric resistance boilers are capable of heating any hot water or steam heating system throughout the entire heating season, whereas hydronic heat pumps do not have such capabilities. Crown and U.S. Boiler stated that heat pumps and boilers provide different consumer utility, and suggested that presenting heat pumps to consumers as "boilers" could create confusion with regard to the different capabilities of each. (Crown, No. 16 at p. 1–2; -U.S. Boiler, No. 17 at p. 1–2)

[11] DOE notes that both Crown and U.S. Boiler's comments stated that the companies are subsidiaries of Burnham Holdings, Inc. ("BHI"). The comments submitted by Crown and U.S. Boiler in response to the March 2022 NOPR were identical in content.

AHRI and AGA and APGA commented that hydronic heat pumps cannot currently provide the same functionality as boilers for high temperature installations as they are unable to provide water at or over 210 °F, and that this lack of utility should disqualify these products from being considered in the boiler test procedure. (AHRI, No. 26 at p. 2; AGA and APGA, No. 25 at p. 2)

BWC disagreed with DOE's tentative determination that air-to-water and water-to-water heat pumps should be defined as consumer boilers. BWC stated that heat pump products and consumer boilers have pronounced differences that should prevent them from being defined as the same product. BWC noted that boilers and heat pumps[12] are already separate product categories on DOE's website and certified separately through DOE's Compliance Certification Management System. BWC also stated that hydronic heat pumps are rated to Coefficient of Performance ("COP") rather than AFUE (for boilers), and that the unique technologies utilized by both product types necessitate different methods for testing and rating them. BWC further stated that consumer boilers are designed exclusively to provide a heating utility, whereas hydronic heat pumps can be used to provide both space heating and cooling. (BWC, No. 19 at p. 2–3)

Rheem supported DOE's tentative determination that hydronic air-to-water and water-to-water heat pumps are consumer boilers under EPCA. Rheem stated that although these products may not necessarily be able to achieve the same maximum temperatures as conventional boilers (without electric resistance or gas backup), hydronic heat pump boilers can still provide adequate space heating in many applications. Rheem recommended that DOE either add procedures to test hydronic heat pumps in this consumer boiler test procedure rulemaking or initiate a separate test procedure

[12] DOE understands BWC is referring to central air conditioning and heat pump units.

rulemaking. Rheem asserted that these products perform the same function as other types of boilers and should be tested and rated in a similar manner, and that DOE could use the current AFUE test procedure as a guide to produce an "AFUE metric" for hydronic heat pumps that combines the various energy use modes and input rate conditions with test conditions and operating assumptions that are representative of hydronic heat pumps. Rheem stated that any differences in ability to meet consumer heating demands should be considered in the development of energy conservation standards, as opposed to the test procedure. (Rheem, No. 18 at p. 2)

NYSERDA agreed with DOE's tentative determination that air-to-water and water-to-water heat pumps should be considered boilers under EPCA. NYSERDA recommended that DOE develop a test procedure for these heat pumps and combination space heating and water heating products. NYSERDA asserted that the adoption of these test procedures will also enable future standards revisions to adopt more efficient heat pump levels of performance. (NYSERDA, No. 23 at p. 5–6)

In consideration of the comments received on this issue, as well as further consideration of the discussion presented in the March 2022 NOPR, DOE has concluded that hydronic air-to-water and water-to-water heat pumps meet the definitional criteria to be classified as a consumer boiler. In particular, as noted initially in the March 2022 NOPR, DOE concludes that these products utilize only single-phase electric current, are designed to be the principal heating source for the living space of a residence, and are not contained within the same cabinet with a central air conditioner whose rated cooling capacity is above 65,000 Btu/h. In addition, electric heat pump boilers meet the definition of an electric boiler; and gas-fired heat pump boilers meet the definition of a low pressure steam or hot water boiler and have a heat input rate of less than 300,000 Btu/h (*i.e.*, the

requirement for electric boilers and low pressure steam or hot water boilers). As such, these products meet the criteria of "furnace" as defined in 10 CFR 430.2.

With respect to comments from Crown, U.S. Boiler, AHRI, and AGA and APGA suggesting hydronic air-to-water heat pumps and water-to-water heat pumps should be excluded from the definition because they cannot provide the same maximum water temperature as non-heat pump hydronic systems, DOE notes that neither EPCA nor DOE's definitions at 10 CFR 430.2 provide a minimum water temperature requirement. In addition, in response to comments that hydronic heat pumps serve different applications than boilers, DOE notes that hydronic heat pumps are marketed as providing the principal heating source for a residence, and nothing in EPCA's or DOE's definition would exclude them based on their ability to also provide cooling.

DOE recognizes that hydronic heat pump products differ significantly from non-heat pump boilers, and that the current test procedure for consumer boilers (as well as the amended test procedure established by this final rule) would not provide test results that are representative of the energy use or energy efficiency of an air-to-water or water-to-water heat pump product. Because of these differences and uncertainty regarding the most representative approach to testing these products, DOE is not establishing separate test procedures for hydronic heat pump products in this final rule. Although air-to-water and water-to-water heat pump products meet all the definitional criteria to be considered a consumer boiler, the Department requires more information in order to determine a representative approach for testing these products. Further consideration of an appropriate test procedure for such products would be provided in a separate test procedure rulemaking. Section III.C of this document further discusses the applicability of the AFUE metric to hydronic heat pump products.

B. Definitions

In addition to the overarching definition of "furnace" (which includes boilers) and the associated definitions for "electric boiler" and "low pressure steam or hot water boiler" presented in section III.A of this document, DOE also has defined "outdoor boilers" and "weatherized warm air boilers" at 10 CFR 430.2 as follows:

- "Outdoor furnace or boiler" is a furnace or boiler normally intended for installation out-of-doors or in an unheated space (such as an attic or a crawl space).

- "Weatherized warm air furnace or boiler" means a furnace or boiler designed for installation outdoors, approved for resistance to wind, rain, and snow, and supplied with its own venting system.

In the March 2022 NOPR, DOE proposed to remove the definition of "outdoor furnace or boiler" from its regulations, noting that the definition is not used for the energy conservation standards for boilers at 10 CFR 430.32(e)(2)(iii), nor for applying the test procedure.[13] 87 FR 14622, 14626-14627. DOE sought comment on its proposal to remove the definition of "outdoor furnace or boiler" from its regulations and whether removing the definition for "outdoor furnace or boiler" would impact the application of the test procedure or energy conservation standards for any such products.

[13] Specifically, with respect to the test procedure, DOE noted that different jacket loss factors are applied based on whether a boiler is intended to be installed indoors, outdoors, or as an isolated combustion system. The heating seasonal efficiency ($Effy_{HS}$) calculation, which is an element of AFUE, is based on the assumption that all weatherized boilers are located outdoors (see section 10.1 of appendix N). Appendix N does not specify a separate jacket loss assumption for outdoor furnaces or boilers.

Rheem and BWC supported DOE's proposal to remove the definition of "outdoor furnace or boiler" from 10 CFR 430.2. (Rheem, No. 18 at p. 2; BWC, No. 19 at p. 1) A.O. Smith stated that removal of this definition from the DOE regulations would not have a negative impact on the application of the test procedure or energy conservation standards. (A.O. Smith, No. 24 at p. 2) AHRI and AGA and APGA also supported removing the definition and stated that the removal would add clarity and consistency to the test procedure. (AHRI, No. 26 at p. 2; AGA and APGA, No. 25 at p. 2)

For the reasons discussed in the March 2022 NOPR, and in consideration of these comments, in this final rule DOE finalizes its proposal to remove the definition of "outdoor furnace or boiler" from 10 CFR 430.2.

In the March 2022 NOPR, DOE proposed to incorporate by reference ANSI/ASHRAE 103-2017, including the definitions included therein. 87 FR 14622, 14627. DOE noted that ANSI/ASHRAE 103-2017 includes definitions for "air intake terminal," "control," and "isolated combustion system" that are not in ANSI/ASHRAE 103-1993. *Id*. The definitions for "control" and "isolated combustion system" in ANSI/ASHRAE 103-2017 are almost identical to the definitions for those terms currently defined in sections 2.3 and 2.7 of appendix N, respectively. Therefore, DOE proposed to remove the definitions for "control" and "isolated combustion system" from DOE's consumer boiler test procedure, as they would be redundant with the definitions incorporated by reference through ANSI/ASHRAE 103-2017, if the proposal to incorporate by reference ANSI/ASHRAE 103-2017 were finalized. *Id.*

Rheem, The CA IOUs, A.O. Smith, AHRI, and AGA and APGA supported incorporating by reference the definitions in ANSI/ASHRAE 103-2017 and removing the

separate definitions for "control" and "isolated combustions system" from DOE's test procedure. (Rheem, No. 18 at p. 3; CA IOUs, No. 20 at p. 1; A.O. Smith, No. 24 at p. 3; AHRI, No. 26 at p. 2; AGA and APGA, No. 25 at p. 2)

For the reasons discussed in the March 2022 NOPR, and in consideration of these comments, DOE is removing the separate definitions for "control" and "isolated combustion system" from the consumer boiler test procedure, as proposed in the March 2022 NOPR. The definitions for these products are instead provided through DOE's incorporation by reference of ANSI/ASHRAE 103-2017, as discussed further in section III.D.1 of this final rule.

In response to the March 2022 NOPR, Busse suggested that DOE add a definition for "standard cubic unit of gas" as follows:

"Standard cubic foot of gas: The amount of gas that would occupy 1 cubic foot when at a temperature of 60 °F, if saturated with water vapor, and under a pressure equivalent to that of 30 inches mercury column." (Busse, No. 22 at p. 9)

Busse stated that a definition of standard cubic foot of gas is necessary to comply with the conditions specified in section 7.1 of appendix N, *Fuel Supply*.[14] Busse further stated that the suggested definition would be consistent with industry standards NFPA 54/ANSI Z223.1, *National Fuel Gas Code*, and CSA 4.9/ANSI Z21.13, *Gas-Fired Low Pressure Steam and Hot Water Boilers* and asserted that manufacturers are familiar with this definition when conducting performance testing. Busse noted that the difference between a saturated "wet" and unsaturated "dry" cubic foot of gas is 1.73 percent at

[14] Section 7.1 of appendix N requires determining the actual higher heating value in Btu per standard cubic foot for the gas to be used in the test within an error no greater than 1 percent.

standard temperature and pressure. Busse also recommended that DOE modify the language of section 7.3 of appendix N, *Gas Burner*, to replace "gas characteristics at a temperature of 60 °F and atmospheric pressure of 30 in of Hg" with reference to this new definition, *i.e.*, "gas characteristics to standard cubic foot of gas, as defined in section 2 of this appendix," in specifying the conditions needed to correct the burner input rate.[15] (Busse, No. 22 at p. 9–10)

In response, DOE notes that as proposed in the March 2022 NOPR, section 7.3 of appendix EE would require that the burner input rate be corrected to reflect gas characteristics at a temperature of 60 °F and atmospheric pressure of 30 in of Hg when adjusting the burner input rate. Therefore, an additional definition for a standard cubic foot of gas for the purpose of referencing it in sections 7.1 and 7.3 (which is consistent with the language in section 9.1.2.2.1 of both ANSI/ASHRAE 103-1993 and ANSI/ASHRAE 103-2017) would be unnecessary; however, it may be useful for clarification.

As such, DOE is adding a definition for a "standard cubic foot of gas" to section 2 of appendix EE to specify the temperature and pressure for a standard cubic foot of gas.

C. Metric

As discussed, the energy conservation standards for consumer boilers rely on the AFUE metric. 10 CFR 430.32(e)(2). For gas-fired and oil-fired boilers, AFUE accounts for fossil fuel consumption in active, standby, and off modes, but does not include electrical energy consumption. For electric boilers, AFUE accounts for electrical energy

[15] Busse also commented that, with respect to the current instruction to "Correct the burner input rate to reflect gas characteristics," technically the Ideal Gas Laws can be applied only to the volume of gas consumed and the higher heating value, and not to the burner input rate.

consumption in active mode. EPCA defines the term "annual fuel utilization efficiency," in part, as the efficiency descriptor for furnaces and boilers. (42 U.S.C. 6291(20)) In addition, DOE has established separate metrics and energy conservation standards for power consumption during standby mode and off mode ($P_{W,SB}$ and $P_{W,OFF}$, respectively). 10 CFR 430.32(e)(2)(iii)(B).

AFUE is defined by ASHRAE 103 (both the 1993 and 2017 versions) as the ratio of annual output energy to annual input energy, which includes any non-heating-season pilot input loss but does not include electric energy for gas- or oil-fired furnaces or boilers. For gas- and oil-fired boilers, the AFUE test generally consists of steady-state, cool down, and heat up tests, during which various measurements are taken (*e.g.*, flue gas temperature, concentration of CO_2 in the flue gas). (*See* sections 9.1, 9.5, and 9.6 of both ANSI/ASHRAE 103-1993 and ANSI/ASHRAE 103-2017.) For condensing boilers, condensate collection tests during steady-state and cyclic operation are also specified. (*See* sections 9.2 and 9.8 of both ANSI/ASHRAE 103-1993 and ANSI/ASHRAE 103-2017.) The test measurements are used in conjunction with certain assumptions to calculate the AFUE. (*See* section 11 of both ANSI/ASHRAE 103-1993 and ANSI/ASHRAE 103-2017.)

In the March 2022 NOPR, after tentatively concluding that hydronic heat pumps meet the definitional criteria to be considered a consumer boiler but that the existing test procedure does not apply to them, DOE sought comment on whether any other industry test methods exist for determining the heating efficiency of air-to-water or water-to-water heat pumps. DOE sought comment specifically on AHRI 550/590, and whether it would be appropriate for adoption as a Federal test procedure for such products, and if so, whether modifications could be made to result in an AFUE rating. 87 FR 14622, 14626.

NYSERDA urged DOE to adopt appropriate, industry-recognized test procedures to support informed consumer choice between electric resistance and heat pump products. (NYSERDA, No. 23 at p. 5–6)

BWC stated that it believes DOE has correctly identified the appropriate test procedures for both consumer boilers and hydronic heat pumps at this time, with those procedures being ASHRAE 103-2017 and AHRI 550/590 respectively. (BWC, No. 19 at p 2–3) Rheem identified AHRI 550/590 as an industry test method to determine maximum and part-load COP values but noted this test method would have to be modified to account for standby mode and off mode energy use as well as to produce an AFUE metric. (Rheem, No. 18 at p. 2)

The Joint Advocates stated that while AHRI 550/590 is appropriate for evaluating the performance of consumer air-to-water heat pumps, it is only applicable for water-to-water heat pumps with a capacity greater or equal to 135,000 Btu/h. The Joint Advocates stated that ASHRAE/ANSI/AHRI/ISO Standard 13256-2 is more appropriate for consumer water-to-water heat pumps and referred to international standards EN 14511 and EN 14825 as starting points. The Joint Advocates asserted that a seasonal performance rating analogous to AFUE could be established and encouraged DOE to establish these procedures in a timely manner so that consumers have access to efficiency ratings based on a standardized test procedure. Finally, the Joint Advocates stated that based on 2015 Residential Energy Consumption Survey ("RECS") data, hydronic systems are the main heating means in 8 percent of U.S. homes overall and the main heating means for 28 percent of households in the Northeastern United States. (Joint Advocates, No. 21 at p. 1–2)

A.O. Smith stated that ISO Standard 13256-2 would be the most appropriate test method for water source heat pump water heaters intended to be used as consumer hot water boilers, and that AHRI Standard 550/590 would be the most appropriate test method for air source heat pump water heaters intended to be used as consumer hot water boilers. Pertaining specifically to AHRI 550/590, A.O. Smith stated that the test procedure to measure COP has fundamental differences than the test procedure to measure AFUE, and that there is no means of deriving an AFUE value from the COP measurement. In addition, A.O. Smith claimed that if the limit for consumer heat pump water "boilers" is defined by an input rate of less than 300,000 Btu/h, then the output for these products will include products with heating capacities up to 900,000 Btu/h, which would be outside the scope of a consumer boiler. A.O. Smith recommended that DOE review the referenced performance standards, as they define the heating capacity based on the heat moved into the water being heated, whereas DOE's definition is based on the energy being consumed by the boiler. (A.O. Smith, No. 24 at p. 2)

As stated in section III.A.2 of this document, DOE has concluded that hydronic heat pumps meet the definitional criteria to be covered as a consumer boiler under EPCA's statutory definition at 42 U.S.C. 6291(23) and DOE's regulatory definition at 10 CFR 430.2. However, DOE is not adopting a separate test procedure or metric for hydronic heat pumps in this final rule because the Department requires more information in order to determine a representative approach for testing these products. DOE will continue to consider the appropriate metric to assess the efficiency of such products, and any proposed test procedure would be addressed in a separate test procedure rulemaking in the future.

D. Updates to Industry Standards

The DOE test method for consumer boilers references several industry standards, including ANSI/ASHRAE 103 for various testing requirements pertaining to determination of AFUE, certain sections of IEC 62301 (Second Edition) for determining the electrical standby mode and off mode energy consumption, and ASTM D2156-09 (Reapproved 2013) for adjusting oil burners. The following sections discuss DOE's amendments pertaining to the incorporation by reference of these industry standards.

1. ANSI/ASHRAE 103

As discussed, ANSI/ASHRAE 103-1993 is referenced throughout appendix N for various testing requirements pertaining to determination of the AFUE of consumer boilers. ANSI/ASHRAE 103-1993 provides procedures for determining the AFUE of consumer boilers (and furnaces). As mentioned previously, ANSI/ASHRAE 103-1993 has been updated multiple times. In the rulemaking that culminated in the January 2016 Final Rule, DOE initially proposed to incorporate by reference the most recent version of ANSI/ASHRAE 103 available at the time (*i.e.*, ANSI/ASHRAE 103-2007), but ultimately declined to adopt the proposal in the final rule based on concerns about the impact this change would have on AFUE ratings of products distributed in commerce at that time. 81 FR 2628, 2632–2633 (Jan. 15, 2016). DOE stated that further evaluation was needed to determine the potential impacts of ANSI/ASHRAE 103-2007 on the measured AFUE of boilers. *Id.* DOE theorized that ANSI/ASHRAE 103-2007 might better account for the operation of two-stage and modulating products and stated that DOE may further investigate adopting it or a successor test procedure in the future. *Id.*

After the January 2016 Final Rule, ANSI/ASHRAE 103 was again updated in 2017 (*i.e.*, ANSI/ASHRAE 103-2017). In the May 2020 RFI, DOE identified several

substantive differences between ANSI/ASHRAE 103-1993 and ANSI/ASHRAE 103-2017 that pertain to consumer boilers and requested further comment on the differences between ANSI/ASHRAE 103-1993 and ANSI/ASHRAE 103-2017. 85 FR 29352, 29355.

In the March 2022 NOPR, DOE discussed additional differences between ANSI/ASHRAE 103-1993 and ANSI/ASHRAE 103-2017 raised by commenters in response to the May 2020 RFI. 87 FR 14622, 14628-14631. The differences between the two versions of the standard are discussed in detail in sections III.D.1.a through III.D.1.f of this document. After considering the differences between the standards and the potential impact, DOE proposed to incorporate by reference the most recent version (at the time) of ANSI/ASHRAE 103, *i.e.*, ANSI/ASHRAE 103-2017. 87 FR 14622, 14630. DOE tentatively concluded that the improvements included in ANSI/ASHRAE 103-2017 provide a more representative average use cycle for consumer boilers, in particular for two-stage and modulating boilers, and that the change would not materially alter the burden or cost of conducting an AFUE test. *Id*. DOE also noted that test data indicate the update to the 2017 edition of ASHRAE 103 could result in changes to the measured AFUE of two-stage and modulating boilers ranging from -0.50 percent to 0.23 percent, with no discernable trend in the direction or magnitude of change, and that several commenters indicated incorporating ANSI/ASHRAE 103-2017 would likely not impact rated values significantly. 87 FR 14622, 14631. DOE sought further comment on its proposal to incorporate by reference ANSI/ASHRAE 103-2017, the potential impact on ratings and whether retesting would be required. *Id*.

Rheem agreed with DOE's tentative determination that the proposed amendments would result in minimal differences in AFUE ratings but requested that DOE test a

representative sample of minimally compliant consumer boilers to determine the effect. Rheem requested that DOE provide this test data in the final rule and assess the impacts on the ongoing energy conservation standards rulemaking. Rheem additionally suggested that DOE could provide an enforcement policy to state that models tested and certified prior to the effective date of the test procedure final rule would be tested to the current appendix N test procedure during an enforcement investigation. (Rheem, No. 18 at p. 3–4)

As discussed, DOE's assessment of the changes in ANSI/ASHRAE 103-2017, along with stakeholder comments provided throughout this rulemaking, indicate that the only update in the industry test procedure with the potential to impact ratings would be the change in cycle times. This topic is discussed in detail in section III.D.2.c of this document. The updated cycle times pertain to condensing boilers, which employ heat exchanger technologies with efficiency performance that surpasses the current minimum AFUE requirements for boilers at 10 CFR 430.32(e)(2)(iii). As discussed in section III.D.2.c of this document, DOE conducted testing to determine that the impact on AFUE ratings of this change would be minimal. Based on this information, DOE has determined that the amendments to the consumer boilers test procedure will not have a significant or substantive impact on ratings, nor affect compliance of any products.

On January 10, 2022, ASHRAE and ANSI approved a 2022 edition of ASHRAE 103 (*i.e.*, "ANSI/ASHRAE 103-2022"). DOE did not discuss ANSI/ASHRAE 103-2022 in the March 2022 NOPR, and parties commenting in response to the March 2022 NOPR did not indicate that DOE should consider incorporating by reference ANSI/ASHRAE 103-2022. A March 4, 2022, online publication by ANSI states that ANSI/ASHRAE 103-2022 includes mostly editorial changes and quality improvements to test duct and

plenum figure, the system number table, and figures for the surface heat transfer coefficient and coefficient of radiation.[16] Given that stakeholders provided general support for adopting ANSI/ASHRAE 103-2017, and that the updates in ANSI/ASHRAE 103-2022 do not substantively change the industry test procedure DOE is not considering ANSI/ASHRAE 103-2022 in this rulemaking.

The following subsections discuss the updates in ANSI/ASHRAE 103-2017 with respect to ANSI/ASHRAE 103-1993.

a. Post-Purge Time

Power vented units, power burner units, and forced-draft units use a combustion blower to exhaust the flue gas during operation. "Post purge" is defined in both ANSI/ASHRAE 103-1993 and ANSI/ASHRAE 103-2017 as "the design that permits the continued operation of the combustion blower in a power vented unit, power burner unit, or forced-draft unit for a period of time after the main burner is shut off for the purpose of venting of residential flue gas in the heat exchanger and the venting system." For the determination of off-cycle flue losses, it is necessary to demarcate when the boiler has entered its off-cycle after completion of the post-purge period, especially since post-purge periods can last several minutes. Section 8.7 of appendix N specifies the timing of flue temperature measurements during the off-cycle portion of the test method based on the length of the post-purge period. Section 8.7 of appendix N generally corresponds to section 9.5.2.1 of ANSI/ASHRAE 103-1993, except that section 8.7 of appendix N specifies that when the post-purge time is less than or equal to 30 seconds, it can be set to 0 and the cool-down test be conducted as if there is no post-purge; while section 9.5.2.1

[16] Brad Kelechava, "ANSI/ASHRAE 103-2022: AFUE Testing of Residential Furnaces and Boilers," The ANSI Blog, March 4, 2022, *blog.ansi.org/ansi-ashrae-103-2022-fuel-efficiency-afue-testing/#gref*. Last accessed October 5, 2022.

of ANSI/ASHRAE 103-1993 specifies that if post-purge time is less than or equal to 5 seconds, it shall be tested as if there is no post-purge. Additionally, the length of the post-purge cycle is used as one criterion for determining whether the heat-up and cool-down tests can optionally be omitted. Section 8.10 of appendix N generally corresponds to section 9.10 of ANSI/ASHRAE 103-1993, and both sections require a post-purge period of less than 5 seconds to optionally omit the heat-up and cool-down tests.

Section 9.5.2.1 of ANSI/ASHRAE 103 was updated in the 2017 version to match DOE's requirement that if the post-purge period is 30 seconds or less, it shall be tested as if there is no post-purge. Additionally, in the March 2022 NOPR, DOE identified the post-purge time threshold being increased to 30 seconds in the criterion for determining whether the "Optional Test Procedures for Conducting Furnaces and Boilers that have no OFF-Period Flue Loss" is applicable as a change in ANSI/ASHRAE 103-2017. DOE proposed to adopt the 30-second threshold in the newly proposed appendix EE, consistent with the change to ANSI/ASHRAE 103-2017. 87 FR 14622, 14628.

BWC stated that it appreciated DOE's inclusion of the change in post-purge time length to 30 seconds. (BWC, No. 19, p. 2–3)

Additionally, in the March 2022 NOPR, DOE proposed minor changes to the test method for models with post-purge times longer than 3 minutes, consistent with the updates included in ANSI/ASHRAE 103-2017. 87 FR 14622, 14631. Specifically, section 9.5.2.1 of ANSI/ASHRAE 103-2017 requires that for cases where the post-purge period is greater than 3 minutes, an additional measurement of the flue gas temperature during the cool-down test is required at the midpoint of the post-purge period. DOE

proposed to adopt a harmonizing change in the newly proposed appendix EE. 87 FR 14622, 14631 and 14654.

DOE did not receive any comments regarding this proposal. For the reasons discussed in the March 2022 NOPR, DOE is finalizing this amendment to section 8.5(d) of appendix EE.

b. Calculations for Omission of Heat-Up and Cool-Down Tests

The current test procedure for consumer boilers allows certain units to omit the cool-down and heat-up tests. These include units that have been determined to have no measurable airflow through the combustion chamber and heat exchanger during the burner off-period and that have minimal post-purge periods (see section III.D.1.a of this document for discussion of post-purge time). For these boilers, the off-cycle losses are expected to be minimal. However, off-cycle losses (typically determined during the cool-down and heat-up tests) must be accounted for when determining the heating seasonal efficiency, $Effy_{HS}$. Section 8.10 of appendix N currently states, "In lieu of conducting the cool-down and heat-up tests, the tester may use the losses determined during the steady-state test described in section 9.1 of ASHRAE 103-1993 when calculating heating seasonal efficiency, $Effy_{HS}$." Accordingly, sections 10.2 and 10.3 of appendix N provide the appropriate equations to use when calculating $Effy_{HS}$ if the cool-down and heat-up tests are omitted per section 8.10 of appendix N. These equations are provided in sections 10.2 and 10.3 of appendix N because they were not included in ANSI/ASHRAE 103-1993.

As discussed in the March 2022 NOPR, ANSI/ASHRAE 103-2017 makes several updates to include these equations, and the equations in ANSI/ASHRAE 103-2017 are

identical to those in appendix N. 87 FR 14622, 14629. Due to this harmonizing update, DOE proposed not to include these equations in the new appendix EE and to instead directly reference the relevant sections in ANSI/ASHRAE 103-2017 (11.3.11.3, 11.5.11.1, and 11.5.11.2). 87 FR 14622, 14631. DOE did not receive comment on this topic and is finalizing this amendment as proposed in the March 2022 NOPR.

c. Cycle Timings

ANSI/ASHRAE 103-2017 includes calculations, originally included in ANSI/ASHRAE 103-2007, for determining the average on-time and off-time per cycle for two-stage and modulating boilers, rather than assigning fixed values as in ANSI/ASHRAE 103-1993. DOE received comments in response to the May 2020 RFI generally indicating that these updated cycle timings are more representative. DOE referenced test data from the previous rulemaking to ascertain the potential impact of this update and tentatively determined that the new method would be more representative and not unduly burdensome and have minimal impact on AFUE ratings. 87 FR 14622, 14628. Therefore, DOE proposed to adopt the updated cycle times via adoption of the ASHRAE 103-2017 as the reference standard in the newly proposed appendix EE. 87 FR 14622, 14630.

In addition, DOE discussed that data collected for the January 2016 Final Rule[17] for three models of condensing, modulating boilers showed that the changes in on-cycle and off-cycle times resulted in changes in AFUE of 0.11, −0.50, and 0.22 percent, respectively. For two models of non-condensing, modulating boilers, calculating the

[17] These data were presented at a public meeting for the March 11, 2015, NOPR pertaining to test procedures for furnaces and boilers and can be found at *www.regulations.gov/document/EERE-2012-BT-TP-0024-0021*.

AFUE based on the on-cycle and off-cycle times in ANSI/ASHRAE 103-2007 changed the AFUE by 0.11 and −0.14 percent, respectively. 87 FR 14622, 14630.

In response to the March 2022 NOPR, BWC stated that it agreed with DOE's conclusion that the new average use cycle calculations from ANSI/ASHRAE 103-2017 are more representative for modulating boilers and have little impact on efficiency ratings. (BWC, No. 19 at p. 4) The CA IOUs stated the ANSI/ASHRAE 103-2017 on/off time per cycle more accurately represents the typical operation for two-stage, modulating, and condensing boiler technologies. (CA IOUs, No. 20 at p. 1)

AHRI requested that DOE provide more data regarding the impacts of cycle timing on condensing models. (AHRI, No. 26 at p. 3)

In response to this request, DOE has conducted testing on two additional modulating condensing boilers to investigate the impact of the revised cycle timings on AFUE. Data collected from this testing is shown in Table III.1. For this investigation, DOE used the updated steady-state efficiency calculation method discussed in section III.E of this final rule for both the ANSI/ASHRAE 103-1993 and ANSI/ASHRAE 103-2017 results such that the only variable influencing differences in AFUE ratings would be the cycle timings.

Table III.1 Impact of Cycle Timings on AFUE for Modulating Condensing Boilers

Model	ANSI/ASHRAE 103-1993		ANSI/ASHRAE 103-2017		Change in AFUE
	Cycle Timings (mm:ss)	AFUE	Cycle Timings (mm:ss)	AFUE	
Unit No. 1	15:00 on / 15:00 off	90.98%	23:10 on / 11:05 off	91.43%	+0.45%
Unit No. 2	15:00 on / 15:00 off	91.61%	20:29 on / 11:50 off	91.46%	−0.15%

As indicated in Table III.1, the change in cycle timings resulted in insignificant changes to the AFUE values (+0.45 percent and −0.15 percent). These additional sample points are consistent with DOE's tentative determination that impacts to AFUE would be minimal as a result of the updated cycle timings in ANSI/ASHRAE 103-2017. Therefore, manufacturers would not be required to retest and rerate consumer boilers due to this change. Based on the discussion provided in the March 2022 NOPR, consideration of comments from interested parties, and this additional test data, DOE has determined that the updated approach in ANSI/ASHRAE 103-2017 increases the representativeness of the test procedure without being unduly burdensome.

During its testing of these two boilers, DOE recognized that the determination of cycle timings in Table 7 of ANSI/ASHRAE 103-2017 does not specify the precision to which these timings (t_{ON} and t_{OFF}) should be calculated (*i.e.*, to the nearest minute or second). ANSI/ASHRAE 103-2017 provides no indication of whether these cycle timings can or should be rounded. Acknowledging that many testing facilities may only be able to time the burner cycling operation of the boiler under test to the nearest second, DOE is providing additional specification in appendix EE to require that calculated cycle timings shall be rounded to the nearest second. This clarification is not expected to impact results significantly but serves to improve repeatability and reproducibility of test results by clarifying the duration of the cycle time.

d. Oversize Factor

The oversize factor for a boiler indicates the ratio between the boiler's nominal capacity and the home's heating load. This factor is represented by the symbol "α" and is determined in sections 11.2.8.3 and 11.4.8.3 of ANSI/ASHRAE 103-1993 and sections 11.2.8.2 and 11.4.8.2 of ANSI/ASHRAE 103-2017.

ANSI/ASHRAE 103-2017 updates the method for calculating the oversize factor. While the oversize factor was calculated from a lookup table based on design heating requirement ("DHR") in ANSI/ASHRAE 103-1993, ANSI/ASHRAE 103-2017 assigns a constant value of 0.70 to α to represent the national average oversize factor. Based on DOE's assessment of its test data, DOE stated in the March 2022 NOPR that this change would be unlikely to have a substantive impact on AFUE ratings because the calculations are not particularly sensitive to changes in the oversize factor value. Specifically, DOE reviewed test data for three modulating, condensing boilers and found that the change in oversize factor from a calculated value, as specified in ANSI/ASHRAE 103–1993, to 0.7 changed the AFUE rating by 0.01 AFUE percentage points or less for all 3 models. 87 FR 14622, 14629. In the March 2022 NOPR, DOE proposed to adopt the constant 0.7 oversize factor through incorporation by reference of ANSI/ASHRAE 103-2017. *Id*.

BWC supported DOE's proposal to adopt the constant 0.7 oversize factor through incorporation of ANSI/ASHRAE 103-2017. BWC's analysis of this proposal demonstrated that adopting this approach would not have a significant impact on overall product efficiency. (BWC, No. 19 at p. 3)

Busse stated that the oversize factor should be a constant value less than 0.4 based on an Air Conditioning Contractors of America ("ACCA") equipment selection checklist[18] indicating to installers that the selected equipment should be less than or equal to 140 percent of the designed total heating load. Busse commented that in the last 40

[18] ACCA "Verifying ACCA Manual S® Procedures" brochure, *www.acca.org/HigherLogic/System/DownloadDocumentFile.ashx?DocumentFileKey=2f0a6828-2205-e112-745f-7215c9a85541&forceDialog=0*. Last accessed October 7, 2022.

years, it has become apparent that oversized equipment is less efficient, such that a more appropriate oversize factor of approximately 0.35 is justified. (Busse, No. 22 at p. 6–7)

In response, DOE notes that commenters did not provide field statistics that would help to determine what a national average representative oversize factor would be, nor is DOE aware of any such data. While contractors may be oversizing boilers to a lesser degree today than in the past, DOE expects that many replacements will be made on a like-for-like basis such that the input capacity of the replacement boiler will match that of the previous boiler (and thus maintain the same oversize factor as the previous boiler). Without sufficient nationally representative data to support deviation from the industry-accepted oversize factor specified in ANSI/ASHRAE 103-2017, DOE is adopting the provision to use a constant oversize factor of 0.70 through incorporation by reference of ANSI/ASHRAE 103-2017. In addition, as discussed previously in this document and initially discussed in the March 2022 NOPR, based on a review of its test data DOE has determined that this change would not substantively impact on AFUE.

e. Annual Performance Metrics

ANSI/ASHRAE 103-2017 changes the method for determining national average burner operating hours ("BOH"), average annual fuel energy consumption ("E_F"), and average annual auxiliary electrical energy consumption ("E_{AE}")[19], especially for two-stage and modulating products, based on a 2002 study from NIST.

The CA IOUs stated that ASHRAE 103-2017 utilizes differentiating calculations for annual operating hours and reduced fuel input rates that reflect real-world operation conditions of boilers that more accurately represents the typical operation for two-stage,

[19] A typographical correction to the determination of E_{AE} at 10 CFR 430.23(n) is discussed in section III.F.5 of this final rule.

modulating, and condensing boilers that spend a significant amount of time operating at part-load conditions. (CA IOUs, No. 20 at p. 1)

These additional annual performance metrics are not required for representations or certifications to DOE at this time. Federal Trade Commission product labeling requirements at 16 CFR 305.8 specify that determinations of estimated annual energy consumption, estimated annual operating cost, and energy efficiency rating must be determined in accordance with the testing and sampling provisions required by DOE as set forth in subpart B of 10 CFR part 430. For boilers, the product labeling provisions are specified at 16 CFR 305.20(f) and currently only require AFUE to be presented. Thus, manufacturers are not required to report BOH, E_F, or E_{AE} for consumer boilers as of this final rule. However, manufacturers may voluntarily represent these values. To ensure that any voluntary representations of these values are conducted in accordance with the DOE test procedure, DOE is adopting the revised calculation methods in ANSI/ASHRAE 103-2017 for BOH, E_F, and E_{AE}.

f. Measurement of Relative Humidity

The current DOE test procedure at appendix N, through incorporation by reference of ANSI/ASHRAE 103-1993, specifies limitations on the relative humidity of the ambient air of the test chamber when testing a condensing boiler. Sections 9.2 and 9.8.1 of ANSI/ASHRAE 103-1993 state, "The humidity of the room air shall at no time exceed 80 percent" but do not provide instruction on the instrumentation necessary to measure the relative humidity. ANSI/ASHRAE 103-2017 provides new requirements in section 8.5.1 to follow ANSI/ASHRAE 41.6-2014 in order to measure relative humidity for testing condensing boilers. Because the DOE test method and ANSI/ASHRAE 103-1993 currently limit relative humidity allowed during testing, DOE reasoned in the

March 2022 NOPR that relative humidity already must be measured under the current procedure; thus, DOE tentatively concluded that the method prescribed by ANSI/ASHRAE 103-2017 would likely be similar to current practices and requested comment on this topic. 87 FR 14622, 14636–14637.

Busse suggested that DOE should verify that ANSI/ASHRAE 41.6-2014 includes precision and calibration requirements. (Busse, No. 22 at p. 9–10) DOE has reviewed ANSI/ASHRAE 41.6-2014 in detail and notes that it provides setup and calibration methods for both psychrometers and hygrometers (two types of instruments which can be used to measure relative humidity). Section 6 of ANSI/ASHRAE 41.6-2014 provides calibration requirements, and sections 7 and 8 of ANSI/ASHRAE 41.6-2014 provide measurement methods, precision requirements, and measurement uncertainty analysis.

As discussed further in section III.K of this document, DOE received comments indicating that introducing these new requirements for measurement and instrumentation would not be unduly burdensome to industry. In this final rule, DOE is incorporating by reference ANSI/ASHRAE 41.6-2014 in appendix EE for the purpose of performing the required humidity measurement.

2. IEC 62301 and ASTM D2156-09

DOE noted in the May 2020 RFI that the version of IEC 62301 currently incorporated by reference in appendix N is still the most recent version, and the most recent iteration of ASTM D2156-09 is a version reapproved in 2018 that did not contain any changes from the 2009 version. 85 FR 29352, 29355. DOE did not receive any comments pertaining to its incorporation by reference of IEC 62301 or ASTM D2156-09 and in the March 2022 NOPR proposed to maintain the current reference to IEC 62301,

and to update the reference to ASTM D2156-09 to reflect the version that was reapproved in 2018. 87 FR 14622, 14628. DOE did not receive any comments related to its incorporation by reference of these standards. In this final rule, DOE is finalizing their adoption for appendix EE as proposed.

E. Steady-State Efficiency for Condensing Modulating Boilers

In the May 2020 RFI and the March 2022 NOPR, DOE discussed that ANSI/ASHRAE 103-1993 and ANSI/ASHRAE 103-2017 yield a circular reference when calculating the steady-state efficiency for condensing modulating boilers. 85 FR 29352, 29357; 87 FR 14622, 14629.

As discussed in the March 2022 NOPR, the circular reference arises within the calculation of steady-state efficiencies at maximum and minimum input rate, which depends in part on the steady-state heat loss due to condensate going down the drain at the maximum and reduced input rates. (*See* section 11.5.7.3 of ANSI/ASHRAE 103-2017, which refers to section 11.3.7.3.) The steady-state heat loss due to condensate going down the drain at the maximum and minimum input rates is calculated in part based on the national average outdoor air temperature at the maximum and minimum input rates. (*See* section 11.5.7.2 of ANSI/ASHRAE 103-2017, which refers to section 11.3.7.2.) The national average outdoor air temperatures at the maximum and minimum input rates are both a function of the balance point temperature. (*See* section 11.5.8.3 of ANSI/ASHRAE 103-2017, which refers to section 11.4.8.3.) The balance point temperature is calculated based on the oversize factor at maximum input rate (which is, as discussed previously, a constant value in ANSI/ASHRAE 103-2017) and the ratio of the heating capacity at the minimum input rate to the heating capacity at the maximum input rate. (*See* section 11.5.8.4 of ANSI/ASHRAE 103-2017, which references section

11.4.8.4.) The heating capacities at the minimum and maximum input rates are calculated based in part on the steady-state efficiencies at minimum and maximum input rates, respectively. (*See* section 11.5.8.1 of ANSI/ASHRAE 103-2017, which references section 11.4.8.1.) If the calculations were interpreted to refer back to the steady-state efficiencies at minimum and maximum input rates for a modulating, condensing model, as determined by section 11.5.7.2 of ANSI/ASHRAE 103-2017, a circular reference would result.

However, since there is no specific instruction to use the values as calculated by section 11.5.7.2, DOE stated in the March 2022 NOPR that it interprets ANSI/ASHRAE 103-2017 to instruct that the steady-state efficiency at maximum and reduced input rates be determined as specified in section 11.4.8.1, which refers to section 11.4.7, which in turn refers to section 11.2.7 for the calculation of steady-state efficiency for non-condensing, non-modulating boilers. 87 FR 14622, 14629. The steady-state efficiencies at maximum and minimum input calculated using section 11.2.7 can then be used to obtain values for output capacities at the maximum and reduced input, which are needed to calculate the balance point temperature, the average outdoor air temperature at maximum and minimum input, and finally the heat loss due to condensate going down the drain at maximum and minimum input rates. *Id*.

In the March 2022 NOPR, DOE proposed to add provisions to clarify the approach for calculating steady-state efficiencies at maximum and minimum input rates for condensing, modulating boilers using ANSI/ASHRAE 103-2017. 87 FR 14622, 14629. Specifically, DOE proposed to codify provisions in section 10.1.2 of appendix EE to explain how to calculate these values without a circular reference, ultimately by referring back to section 11.2.7 of ANSI/ASHRAE 103-2017. 87 FR 14622, 14655.

Crown, U.S. Boiler, BWC, Rheem, A.O. Smith, AHRI, and AGA & APGA all supported DOE's proposal to provide additional specification that would avoid a circular reference in the test procedure. (A.O. Smith, No. 24 at p. 3; AGA & APGA, No. 25 at p. 2) Rheem recommended that each subsection in section 10.1.2 of appendix EE should not say "previous step" but should refer to the appropriate subsection. Specifically, Rheem recommended that DOE present an equation for balance point temperature, T_C, in which the variables used in the equation reference the relevant sections in ANSI/ASHRAE 103-2017. (Rheem, No. 18 at p. 3) Crown, U.S. Boiler, BWC, and AHRI all recommended the same revision for section 10.1.2 to improve the clarity of the section. (Crown, No. 16 at p. 3; U.S. Boiler, No. 17 at p. 2–3; BWC, No. 19 at p. 3; AHRI, No. 26 at p. 2–3) Specifically, the commenters recommended revising section 10.1.2 to replace the output capacity parameters $Q_{OUT,R}$ and Q_{OUT} as follows:

> 10.1.2 Calculate the balance point temperature (T_C) for condensing, modulating boilers by using the following equation in place of that referenced by 11.5.8.4 [of ANSI/ASHRAE 103-2017]:
>
> $$T_C = T_{SH} - \left[(T_{SH} - T_{OA,T})(1+\alpha)\left(\frac{Q_{IN,R}(100 - L_{L,A} - L_{S,SSR})}{Q_{IN}(100 - L_{L,A} - L_{S,SS})}\right)\right]$$
>
> Where:
>
> T_{SH} = typical average outdoor temperature at which a boiler starts operating, 65 °F
>
> $T_{OA,T}$ = the typical outdoor design temperature, 5 °F
>
> α = oversize factor, as defined in 11.4.8.2 [of ANSI/ASHRAE 103-2017]

Q_{IN} = steady-state nameplate maximum fuel input rate

$Q_{IN,R}$ = steady-state reduced input fuel input rate

$L_{S,SSR}$ = average sensible heat loss at steady state, reduced input operation

$L_{S,SS}$ = average sensible heat loss at steady state, maximum input operation

In reviewing this equation, DOE agrees that the recommended equation adequately resolves the circular reference issue in the same manner as DOE proposed in the March 2022 NOPR, but with a simplified approach to specifying the correct calculations for determining the steady-state efficiency for condensing modulating boilers. Rather than determining Q_{OUT} and $Q_{OUT,R}$ based on the steady-state efficiencies $Effy_{SS}$ and $Effy_{SS,R}$ (using section 11.2.7 of ANSI/ASHRAE 103-2017) to calculate T_C, the suggested equation simply inserts the appropriate variables directly into the equation for T_C, providing the same result. DOE is therefore adopting this revised equation in section 10.1.3 of appendix EE.

F. Corrections and Clarifications

1. Off-Cycle Losses

In response to the March 2022 NOPR, several commenters indicated that ANSI/ASHRAE 103-2017 has a typographical error in the equations used to determine $L_{I,OFF1}$ and $L_{S,OFF1}$ (off-cycle infiltration and sensible losses, respectively). Specifically, Crown and U.S. Boiler stated there is an error in section 11.2.10.8 of ANSI/ASHRAE 103-2017 for the calculation of $L_{I,OFF1}$. Crown and U.S. Boiler stated that the equation for $L_{I,OFF1}$ in ANSI/ASHRAE 103-1993 was erroneous because Q_{IN} was multiplied by 60

when it should have been divided by 60. According to Crown and U.S. Boiler, ASHRAE attempted to correct this error in ANSI/ASHRAE 103-2007, but inadvertently copied the equation for $L_{S,OFF1}$ to $L_{I,OFF1}$ for units having post-purge times below 3 minutes, and this error was not corrected in the 2017 edition. (Crown, No. 16 at p. 3; U.S. Boiler, No. 17 at p. 3) Similarly, Rheem identified this issue involving the factor of 60 in the equations for $L_{S,OFF1}$ and $L_{I,OFF1}$ and asked DOE to evaluate the impact on ratings. (Rheem, No. 18, p. 6)

DOE has examined the equations for $L_{S,OFF1}$ and $L_{I,OFF1}$ in ANSI/ASHRAE 103-2017 and understands that the factor of 60 is used to convert the cycle times (reported in minutes) into hours because the input rate is expressed in terms of Btu/h. Thus, the cycle times must be divided by 60 to convert these values into hours. Section 11.2.10.6 of ANSI/ASHRAE 103-2017 performs this operation correctly for determining $L_{S,OFF1}$, but the factor of 60 is used incorrectly in sections 11.2.10.6 and 11.2.10.8 of ANSI/ASHRAE 103-1993.

As Crown and U.S. Boiler indicated, industry has been aware of this error since the development of ANSI/ASHRAE 103-2007. As such, DOE expects that current ratings are determined based on the corrected use of the factor of 60. In particular, DOE is aware that the Gas Appliance Manufacturers Association (GAMA)[20] developed a computer program to calculate AFUE.[21] DOE has reviewed a version of this program (dated October 15, 2003) and determined this calculation was corrected in the underlying code. Based on this finding, correcting the use of the factor of 60 (by incorporating by reference ANSI/ASHRAE 103-2017) should not affect the ratings of products which

[20] GAMA and the Air-Conditioning and Refrigeration Institute (ARI) merged in 2008 to form AHRI.
[21] In the May 2020 RFI, DOE discussed the industry-developed computer program that calculates AFUE based on ANSI/ASHRAE 103-1993 "AFUE v1.2." This software was most recently updated in April 2004. 85 FR 29352, 29356.

have already been tested and certified. Furthermore, these calculations apply only to consumer boilers that have system numbers 2, 3, or 4 with post-purge times greater than 30 seconds, which DOE understands to be a relatively low fraction of the market based on its own compliance testing.

DOE notes that section 11.2.10.8 of ANSI/ASHRAE 103-1993 provided the correct equation for $L_{I,OFF1}$ for models with post-purge periods that are less than or equal to 3 minutes (albeit with the aforementioned error with the factor of 60).

The equation for $L_{I,OFF1}$ for models with post-purge periods that are greater than to 3 minutes is corrected in ANSI/ASHRAE 103-2017 and is adopted in this final rule through incorporation by reference.

2. Conversion Factor for British Thermal Units

In the March 2022 NOPR, DOE noted inconsistencies in the conversion factors from watts (W) or kilowatts (kW) to British thermal units per hour (Btu/h), in which some sections used a conversion factor of 3.412 and other sections use 3.413. 87 FR 14622, 14634. DOE stated that the conversion factor between watts and Btu/h is generally accepted to be 1 watt = 3.412142 Btu/h (or 1 Btu/h = 0.2930711 watts), as published in the *2021 ASHRAE Handbook—Fundamentals*.[22] *Id*. This value is more appropriately rounded to 3.412 W/(Btu/h); therefore, DOE proposed correcting the test procedures to use 3.412 W/(Btu/h) in all calculations where 3.413 W/(Btu/h) was

[22] *2021 ASHRAE Handbook—Fundamentals (I-P Edition)*. Peachtree Corners, GA: American Society of Heating, Refrigeration and Air-Conditioning Engineers, 2021. Available at *www.ashrae.org/technical-resources/ashrae-handbook/description-2021-ashrae-handbook-fundamentals*.

previously used. *Id*. DOE stated in the March 2022 NOPR that it did not expect this correction to affect AFUE ratings. *Id*.

DOE did not receive comments on this topic. For the reasons discussed here and in the March 2022 NOPR, this final rule implements a conversion factor of 3.412 in each instance within new appendix EE. DOE also amends appendix N—which will remain applicable to consumer furnaces other than boilers—to use the corrected conversion factor.

3. Oil Pressure Instrumentation Error

Section 6.3 of ANSI/ASHRAE 103-2017 states, "Instruments for measuring gas, oil, air, water, and steam pressure shall be calibrated so that the error is no greater than the following." However, the specifications that follow omit the instrumentation requirements applicable to measuring oil pressure. Section 6.3(b) of ANSI/ASHRAE 103-1993 included the oil pressure specification.

In response to the March 2022 NOPR, Rheem commented that DOE should add the oil pressure instrumentation specification from ANSI/ASHRAE 103-1993 to section 5 of the new appendix EE test procedure. (Rheem, No. 18 at p. 6)

This final rule reinstates the omitted provisions from section 6.3 of ANSI/ASHRAE 103-1993 in section 5 of appendix EE.

4. Gas Inlet Conditions

Section 7.1 of appendix N references Table 1 of ANSI/ASHRAE 103-1993 for maintaining the gas supply, ahead of all controls for a furnace,[23] at an acceptable test pressure. The natural gas inlet pressure shall be between the "normal" and "increased" values shown in Table 1 of ANSI/ASHRAE 103-1993. Table 1 in ANSI/ASHRAE 103-2017 provides identical gas inlet pressures to those in ANSI/ASHRAE 103-1993 (this table is presented in section 8.2.1.3 of ASHRAE 103-2017, which is excluded from reference in the current appendix N test procedure). Table 1 also specifies the specific gravity of the test gases. The pressures and specific gravity of the test gases are reproduced in Table III.2 of this document.

Table III.2 Natural Gas Inlet Pressures and Specific Gravity of Test Gases in Table 1 of ANSI/ASHRAE 103-1993 and ANSI/ASHRAE 103-2017

Type	Test Pressure (inches water column)		Specific Gravity (Air = 1.0)
	Normal	Increased	
Natural	7.0	10.50	.65
Manufactured	3.5	5.25	.38
Butane	11.0	13.00	2.00
Propane	11.0	13.00	1.53

In response to the March 2022 NOPR, Crown and U.S. Boiler stated that the gas inlet pressure requirements in section 8.2.1.3 of ANSI/ASHRAE 103-2017 are appropriate and necessary for units with pilot lights because most pilots have no pressure regulation within the appliance itself, and thus the input rate of the pilot is determined in large part by the inlet pressure. Crown and U.S. Boiler noted, however, that since continuous standing pilots are prohibited by EPCA on consumer boilers, such restrictive requirements on the gas inlet pressure are no longer necessary in the Federal test

[23] This term refers to the broader definition of "furnace," which includes warm air furnaces and boilers.

procedure and may place undue burden on test labs. Crown and U.S. Boiler commented that maintaining a 7.0 inches water column ("in. w.c.") minimum inlet pressure is not always possible in some test labs, nor is it necessary as long as the regulator outlet pressure can be maintained, and the nameplate input achieved. Crown and U.S. Boiler further indicated that expensive gas booster equipment may be necessary to meet the 7.0 in. w.c. minimum. Crown and U.S. Boiler stated that gas appliances are generally listed for use up to 14.0 in. w.c. inlet pressure, so there is also no reason to reduce this pressure to 10.5 in. w.c. on a boiler without a continuous pilot in order to provide results that are repeatable and representative of what can be expected in the field. In order to afford labs greater flexibility while still preventing boilers from being tested at gas inlet pressures for which they are not intended to be used in the field, Crown and U.S. Boiler suggested replacing the second sentence of section 8.2.1.3 of ANSI/ASHRAE 103-2017 with: "The gas supply, ahead of all controls for a furnace, shall be maintained at a test pressure within the upper and lower limits shown in the manufacturer's instructions or on the boiler itself. In the absence of any such limits, the gas supply pressure shall be maintained between the normal and increased values shown in Table 1 of ANSI/ASHRAE 103-2017." (Crown, No. 16 at p. 2–3; U.S. Boiler, No. 17 at p. 2)

Busse urged DOE to modify the language in section 7.1 of appendix EE to include the term "approximately" when referring to meeting the specific gravity requirements in Table 1 of ANSI/ASHRAE 103–2017, asserting that the omission of this term suggests that DOE expects the specific gravity to be exactly as shown in Table 1 without providing instrument requirements for measuring. (Busse, No. 22 at p. 10)

At 42 U.S.C. 6295(f)(3)(A), EPCA mandates that gas-fired boilers manufactured on or after September 1, 2012, must not have a constant burning pilot. DOE agrees that

the test procedure requirements in appendix N (which reference Table 1 of ANSI/ASHRAE 103-1993) have a greater contribution to maintaining the reproducibility and repeatability of test results for consumer boilers with constant burning pilots; however, it is currently unclear to DOE what the impacts of updating the natural gas inlet pressure requirements as suggested would be on measured efficiency ratings for boilers without constant burning pilots. Crown and U.S. Boiler did not provide data to indicate that their suggested approach of relying on the manufacturer's instructions for setting natural gas inlet pressure will not significantly impact ratings. Manufacturers have not previously expressed concern regarding the ability to meet the inlet pressure requirements in appendix N, and no waivers have been received for consumer boilers that are not compatible with the inlet pressure provisions. This suggests that manufacturers and test laboratories have been able to meet these setup requirements since compliance with the currently applicable appendix N test procedure has been required (July 13, 2016).

For these reasons, DOE has determined that no correction to the natural gas inlet pressure requirements is necessary at this time and is adopting the reference to Table 1 of ANSI/ASHRAE 103-2017 in section 7.1 of appendix EE as proposed in the March 2022 NOPR. Regarding Busse's suggestion to include the word "approximately" in reference to the specific gravity values referenced in section 7.1, DOE agrees that the specific gravity may not be exactly as provided in Table 1 of ANSI/ASHRAE 103-2017 because variations exist due to differences in gas composition in supply sources. DOE understands that the purpose of specifying the gas characteristics in Table 1 of ANSI/ASHRAE 103-2017 is to ensure that the energy content in the gas is consistent for the repeatability and reproducibility of the test. DOE notes that explicit tolerances are provided for the higher heating value of the gas used, such that providing explicit tolerances for the specific gravity of the gas would be redundant. As such, DOE is

adopting Busse's suggestion to state that the specific gravity of the gas should be "approximately" that shown in Table 1 of ANSI/ASHRAE 103-2017.

5. Active Mode Electrical Energy Consumption

As previously discussed, AFUE does not include active mode electrical consumption for gas-fired and oil-fired boilers. Instead, the DOE test procedure includes provisions for determining the average annual auxiliary electrical energy consumption for gas-fired and oil-fired boilers (E_{AE}), as a separate metric from AFUE, that accounts for active mode, standby mode, and off mode electrical consumption. (See appendix N, section 10.4.3.) E_{AE} is referenced by the calculations at 10 CFR 430.23(n)(1) for determining the estimated annual operating cost for furnaces. However, the provisions at 10 CFR 430.23(n) include several incorrect references to sections in appendix N. In the March 2022 NOPR, DOE proposed to correct 10 CFR 430.23(n)(1) to reference the appropriate sections of appendix N where the currently codified provisions point to the wrong sections. Additionally, DOE proposed to revise 10 CFR 430.23(n)(1) such that sections in appendix N are referenced for furnaces and sections in appendix EE are referenced for boilers. 87 FR 14622, 14633, and 14643.

DOE did not receive any comments on this topic. In this final rule, DOE adopts these corrections as proposed.

6. Circulator Pumps

Section 8.2 of the proposed appendix EE from the March 2022 NOPR included instructions on the electrical energy consumption measurements for various boiler components in order to calculate PE, the electrical power involved in burner operation.

87 FR 14622, 14654. It stated that the measurement of PE must include the boiler pump if so equipped. *Id*.

In response to the March 2022 NOPR, Rheem noted that section 2 of the proposed appendix EE defines a "boiler pump"[24] as being separate from the circulating water pump; however, the term "circulating water pump" is not defined in the proposed appendix EE or ANSI/ASHRAE 103-2017. Rheem recommended that DOE add a definition for "circulating water pump" to clarify the difference between these pumps and to reduce confusion when performing the procedure in section 8.2 of appendix EE, which refers to both pump types. (Rheem, No. 18 at p. 5–6)

DOE notes that the definition for "boiler pump" was established in the January 2016 Test Procedure Final Rule. 81 FR 2628, 2647. In the January 2016 Test Procedure Final Rule, in describing devices that use power during the active mode, DOE discussed a secondary pump for boilers (*i.e.*, boiler pump) used to maintain a minimum flow rate through the boiler heat exchanger, which is most typically associated with condensing boiler designs. *Id.* at 81 FR 2633. In the preamble to the January 2016 Test Procedure Final Rule, DOE stated that it would define a boiler pump as, "a pump installed on a boiler that maintains adequate water flow through the boiler heat exchanger and that is separate from the circulating water pump;" however, this definition was not codified with the additional clarification that the boiler pump maintains adequate water flow through the heat exchanger. *Id.* at 81 FR 2634. In order to improve the clarity of the boiler pump definition, DOE is revising this definition to reflect the language which was inadvertently omitted from the January 2016 Test Procedure Final Rule.

[24] Section 2.2 of appendix N defines a "boiler pump" as a pump installed on a boiler that is separate from the circulating water pump.

Additionally, section 9.1.2.2 of ANSI/ASHRAE 103-2017 states that, for hot water boilers, the circulating water pump nameplate power is to be used to determine the electrical power to the circulating water pump (BE), and if the pump nameplate power is not available, use the pump power listed in the water pump manufacturer's literature or use 0.13 kW. In response to the March 2022 NOPR, Busse suggested that, because circulator pumps do not have a "nameplate" power value, the water pump manufacturer's literature could be used instead for calculating the value of BE. Busse also commented that the default value of 0.13 kW in ANSI/ASHRAE 103-2017 may not be appropriate for modern electronically commutated motor-based circulator pumps. (Busse, No. 22 at p. 11)

At this time, DOE does not have sufficient data on circulating water pumps used with consumer hot water boilers to specify a more representative power draw to be used in lieu of manufacturer-reported information (either on a nameplate or in the I&O manual). As ANSI/ASHRAE 103-2017 is currently the industry-accepted test standard[25] for consumer boilers, DOE expects that the provisions for circulator pump power remain representative for current installations. Additionally, DOE notes that the value of BE is not a factor that determines AFUE (see section III.C for discussion about the AFUE metric).

7. Units with Draft Hoods or Draft Diverters

Section 6.4 of appendix N provides installation instructions for units with draft hoods or draft diverters. Among other requirements, this section specifies installing the stack damper in accordance with the "I&O manual."

[25] ANSI/ASHRAE 103-2022 does not provide substantive updates to provisions for circulator pump power.

In response to the March 2022 NOPR, Rheem commented that section 6.4 of appendix N appeared to have been omitted from the proposed appendix EE. Rheem noted that these provisions are still relevant to boilers and should be carried over into the new appendix EE test procedure. (Rheem, No. 18 at p. 6)

The March 2022 NOPR proposed in section 6 ("Apparatus") of appendix EE to reference section 7 of ANSI/ASHRAE 103-2017 ("Apparatus") including sections 7.2.3.1 and 7.3.3.1. Section 7.3.3.1 of ANSI/ASHRAE 103-2017 specifies stack and flue installation requirements for boilers with draft hoods or draft diverters by referencing section 7.2.3.1 of ANSI/ASHRAE 103-2017. The language in section 7.2.3.1 of ANSI/ASHRAE 103-2017 is identical to the provisions in section 6.4 of the current appendix N, except that section 7.2.3.1 specifies that the stack damper be installed in accordance with the "manufacturer's instructions" rather than the "I&O manual" specified in section 6.4. DOE's proposal to reference sections 7.2.3.1 and 7.3.3.1 of ANSI/ASHRAE 103-2017 through reference to section 7 in the new appendix EE test procedure maintained the installation instructions for units with draft hoods or draft diverters in appendix EE. This final rule maintains the reference to section 7 of ANSI/ASHRAE 103-2017 in section 6 of appendix EE.

DOE has determined, however, that maintaining the more specific reference to the manufacturer's I&O manual, rather than a general reference to manufacturer's instructions, will ensure the reproducibility of the test procedure by providing a more specific reference to the document that must be consulted with regard to installing the stack damper. Therefore, this final rule adds an exception in section 6 of appendix EE to specify referencing the I&O manual in lieu of manufacturer's instructions in section 7.2.3.1 of ANSI/ASHRAE 103-2017.

8. Rounding of AFUE

In response to the March 2022 NOPR, Busse observed an inconsistency between requirements to round the AFUE at 10 CFR 430.23(n)(2)(iii) and requirements to truncate the AFUE at 10 CFR 429.18(a)(2)(vii). (Busse, No. 22 at p. 11)

On July 22, 2022, DOE published a final rule regarding certification requirements for several covered products and equipment, including consumer boilers ("July 2022 Certification Final Rule"). 87 FR 43952. In an amendment established by that final rule, effective August 22, 2022, DOE modified 10 CFR 429.18(a)(2)(vii) to state that AFUE must be rounded to the nearest one-tenth of a percentage point. *Id.* at 87 FR 43968. As this amendment provides consistency between the certification requirement and the test procedure, no further correction is required in this rulemaking.

G. Other Test Procedure Topics

In the course of this rulemaking, DOE solicited feedback on additional aspects of the current test procedure for consumer boilers to assess whether they remain representative of the energy consumption during an average use cycle. DOE did not propose to amend the test procedure for consumer boilers with regard to these topics in the March 2022 NOPR, and after consideration of comments received in response to that NOPR, DOE determined not to amend the test procedure accordingly. Comments received with regard to these topics are discussed in the following subsections.

1. Outdoor Design Temperature

ANSI/ASHRAE 103-2017 assigns a value of 5 °F for the typical outdoor design temperature and 42 °F for the average outdoor air temperature, represented by $T_{OA,T}$ and T_{OA}, respectively. The outdoor design temperature is the lowest expected temperature at

which the boiler can satisfy the home's heating demand, while the average outdoor air temperature is the average temperature during the heating season.

In response to the March 2022 NOPR, Busse stated that the 5 °F outdoor design temperature used in ANSI/ASHRAE 103-1993[26] may be out of date due to climate change and suggested that different outdoor design temperatures could be assigned for furnaces and boilers. (Busse, No. 22 at p. 4) Similarly, Busse indicated that a 42 °F average outdoor air temperature may no longer be valid based on recent climate change data. (Busse, No. 22 at p. 11)

In response, DOE notes that homes in the United States—particularly in the Northeast region, where most boilers are installed—still experience temperatures as low as 5 °F during the heating season[27] despite climate change trends. DOE does not have any data, nor did Busse or other commenters provide any such data, suggesting a value other than 5 °F that would provide more representative test results. As such, DOE is maintaining 5 °F as the outdoor design temperature in the appendix EE test procedure for consumer boilers.

Regarding the average outdoor air temperature, DOE examined average outdoor air temperatures for the contiguous United States during the months of October, November, December, January, February, and March (*i.e.*, the months during which

[26] DOE notes that the same requirement is also specified in ANSI/ASHRAE 103-2017.

[27] For example, daily temperature data for the Albany, NY, area for the winter of 2022 (December 1, 2021, through March 1, 2022) shows 13 days during which the observed temperature reached at or below 5 °F. The Duluth, MN, area experienced 55 days during which the observed temperature reached at or below 5 °F during the same time period. Data for these areas are available at *www.weather.gov/wrh/Climate?wfo=aly* and *www.weather.gov/wrh/Climate?wfo=dlh*. Last accessed October 7, 2022.

consumer boilers would be expected to operate).[28] This data indicates that from 2012 through 2022, average outdoor air temperatures during these months is 41 °F, which aligns closely with the value of 42 °F specified in ANSI/ASHRAE 103-2017. Therefore, in this final rule, DOE is maintaining the value of 42 °F for T_{OA} as specified by ANSI/ASHRAE 103-2017.

2. Ambient Conditions

The current test procedure for consumer boilers in appendix N, through incorporation by reference of ANSI/ASHRAE 103-1993, specifies that the ambient air temperature during testing must be between 65 °F and 100 °F for non-condensing boilers, and between 65 °F and 85 °F for condensing boilers (see section 7 of appendix N and section 8.5.2 of ANSI/ASHRAE 103-1993). In addition, the relative humidity cannot exceed 80 percent during condensate measurement (see section 8 of appendix N and section 9.2 of ANSI/ASHRAE 103-1993).

In the May 2020 RFI, DOE requested comment and data on the effects of ambient temperature and relative humidity on AFUE results, whether the current ranges of allowable conditions adversely impact the representativeness of AFUE values or repeatability of AFUE testing, and whether a narrower range of allowable ambient conditions would increase testing burden. 85 FR 29352, 29356.

As discussed in the March 2022 NOPR, DOE received comments from AHRI and manufacturers supporting the current range of allowable operating conditions, while the

[28] These temperatures are published by the National Oceanic and Atmospheric Administration and are available at *www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/national/time-series*. Last accessed October 7, 2022.

CA IOUs and NEEA suggested limiting this range to reflect the temperatures of spaces where boilers may be installed. 87 FR 14622, 14631.

DOE investigated concerns regarding the ambient conditions as part of the January 2016 Final Rule (*see* 81 FR 2628, 2638; Jan. 15, 2016). Testing conducted in support of the January 2016 Final Rule indicated there was no definitive impact of variation of ambient conditions on the resultant AFUE, and DOE determined there was not adequate data to justify changing the test procedure to narrow the ranges. In the March 2022 NOPR, DOE provided a similar tentative determination based on the lack of sufficient evidence, and thus did not propose any changes at that time. 87 FR 14622, 14631–14632.

In response, while the CA IOUs supported incorporation by reference of ANSI/ASHRAE 103-2017, they encouraged DOE to reexamine the impacts of ambient conditions on AFUE ratings by conducting additional testing. (CA IOUs, No. 20 at p. 2) NYSERDA requested that DOE revise the test procedure to ensure that condensing and non-condensing boilers are tested under the same ambient conditions to allow consumers to make informed decisions between these products. NYSERDA also requested that DOE review the impacts of ambient temperature on boiler performance and review the jacket loss assumptions based on likely real-world operating conditions. Citing that DOE has not provided a further study on ambient conditions since the 2016 rulemaking, NYSERDA urged DOE to revisit the issue of ambient temperature impacts on consumer boiler performance and conduct additional analysis and/or testing either as part of the current rulemaking or in anticipation of the next statutorily mandated review. (NYSERDA, No. 23 at p. 5)

The Joint Advocates stated they did not believe that separate ambient conditions are necessary for non-condensing and condensing boilers, and that the range of allowable ambient temperatures is too broad to accurately measure energy use during a representative average use cycle. The Joint Advocates cited course material from Continuing Education and Development, Inc. indicating that a variation in ambient temperature of 20 °F can affect the thermal efficiency of a commercial package boiler by over 0.5 percent, and therefore suggested that DOE require the ambient temperature to be maintained between 65 °F and 85 °F for all consumer boilers. (Joint Advocates, No. 21 at p. 3)

Busse stated that a boiler tested at the current temperature and humidity limits should perform at a higher AFUE than when tested at a "normal" lab condition of 70 °F and 50 percent relative humidity due to higher water vapor content and higher dew point temperature and thus recommended limiting the test room conditions to 75 °F and 55 percent relative humidity. Busse noted that the National Bureau of Standards Information Report ("NBSIR") recommended limits on the original test room conditions,[29] and that water vapor content and dew point temperature vary significantly with temperature (specifically providing information at 42 °F [average outdoor air temperature], 70 °F ["normal" lab condition], and 85 °F [maximum allowable during AFUE test]). Busse also cited Burnham Holdings, Inc. ("BHI") test data for a single condensing boiler which showed a change in AFUE of 1.3 percent when the relative

[29] Busse's comment references two reports from National Bureau of Information: NBSIR 78-1543: "Recommended Testing and Calculation Procedures for Determining the Seasonal Performance of Residential Central Furnaces and Boilers" (September 1978) and NBSIR 80-2110, "Recommended Testing and Calculation Procedures for Estimating the Seasonal Performance of Residential Condensing Furnaces and Boilers" (April 1981).

humidity was changed from approximately 30 percent to 70 percent. (Busse, No. 22 at p. 5)

DOE notes the data collected thus far has been on a limited sample of boilers, and the information required to amend the ambient conditions should reflect the array of boiler designs on the market. The impact of the ambient air conditions would vary based on how the ambient air interacts with the boiler during its normal operation. As noted previously, in the January 2016 NOPR, DOE concluded that the test data was not definitive enough to provide justification for changing the ambient conditions. Regarding the data submitted by Busse, DOE notes that BHI also provided that data point in a comment responding to the May 2020 RFI (BHI, No. 11 at p. 2, 11). As discussed in the March 2022 NOPR, although BHI provided test data for a single unit showing a difference in performance under different conditions, DOE notes that DOE's previous test data, obtained from multiple units, did not indicate conclusively that ambient test conditions within the current bounds cause substantive differences in AFUE. As a result, DOE is not amending the test procedure for consumer boilers to narrow or revise the ambient test conditions at this time due to insufficient conclusive evidence demonstrating the impact on AFUE for various boiler types.

3. Combustion Settings

In the course of the rulemaking for the January 2016 Final Rule, to provide for greater consistency in burner airflow settings during testing, DOE proposed specifying that the excess air ratio, flue oxygen ("O_2") percentage, or flue carbon dioxide ("CO_2") percentage be within the middle 30th percentile of the acceptable range specified in the I&O manual. 80 FR 12876, 12883, 12906 (Mar. 11, 2015). In absence of a specified range in the I&O manual, DOE proposed requiring the combustion airflow to be adjusted

to provide between 6.9 percent and 7.1 percent dry flue gas O_2, or the lowest dry flue gas O_2 percentage that produces a stable flame, no carbon deposits, and an air-free flue gas carbon monoxide ("CO") ratio below 400 parts per million ("ppm") during the steady-state test described in section 9.1 of ANSI/ASHRAE 103-2007, whichever is higher. 80 FR 12876, 12906. However, after considering comments regarding the representativeness of the proposal and the potential impact on rated AFUE, DOE determined in the January 2016 Final Rule that further study was needed to determine how such changes would impact AFUE ratings. 81 FR 2628, 2636.

In the May 2020 RFI, DOE requested comment on whether more specific instructions for setting the excess air ratio, flue O_2 percentage, and/or flue CO_2 percentage should be provided in the consumer boilers test procedure, and if so, what those instructions should entail. 85 FR 29352, 29356. DOE was particularly interested in understanding whether such a change would improve the representativeness of the test method, and whether it would impact test burden.

In the March 2022 NOPR, after considering comments received in response to the May 2020 RFI, DOE tentatively concluded that it lacked sufficient data and information to indicate that establishing a requirement for setting the excess air ratio, flue O_2 percentage, and/or flue CO_2 percentage would provide ratings that are more representative than the ratings provided under the current approach. Therefore, DOE tentatively determined to maintain the current test procedure and did not propose to establish a requirement for setting the excess air ratio, flue O_2 percentage, and/or flue CO_2 percentage. 87 FR 14622, 14633.

In response to the March 2022 NOPR, the CA IOUs encouraged DOE to examine the impacts of excess air ratio, flue oxygen percentage, and flue carbon dioxide percentage on AFUE ratings by conducting additional testing. (CA IOUs, No. 20 at p. 2) The Joint Advocates also encouraged DOE to investigate the efficiency impacts of combustion airflow settings and to consider establishing criteria around those settings in the test procedure in order to provide more accurate product rankings. The Joint Advocates asserted that excess air, which can be determined by flue gas O_2 and CO_2 concentrations, affects combustion efficiency and, as an example, cited a 2002 fact sheet published by the National Renewable Energy Laboratory that indicated combustion efficiency of commercial boilers can be increased by 1 percent for each 15 percent reduction in excess air ratio.[30] (Joint Advocates, No. 21 at p. 3–4)

NYSERDA recommended that DOE study how excess oxygen impacts the efficiency of the boiler operation. NYSERDA pointed out that DOE received input from multiple stakeholders regarding changes to excess air ratio, flue O_2 percentage, and/or flue CO_2 percentage in the 2016 rulemaking cycle. NYSERDA urged DOE to either revisit this proposal regarding excess oxygen or commit to further study of this topic for a future revision. (NYSERDA, No. 23 at p. 4–5)

Busse suggested updating the test procedure to include two requirements: (1) verify reduced input rate is 98 percent or greater than nameplate minimum input rate and, if less than 98 percent, adjust controls or settings as specified in the I&O manual and restart test at maximum input rate or, if 98 percent or greater, no additional control or setting changes are allowed; and (2) verify combustion products do not exceed 400 parts per million air-free and there are no deposits of carbon on the burner, and correct these

[30] The fact sheet referenced by the Joint Advocates is available at: *https://www.nrel.gov/docs/fy02osti/31496.pdf*. (Last accessed 11/3/2022).

conditions, if necessary, as specified in the I&O manual. Busse stated that a reduced input rate below 98 percent of nameplate minimum input rate would likely result in a higher efficiency, and that requiring adjustment and restarting a test when above 102 percent of nameplate minimum input rate could increase test burden. Busse further stated that these provisions would strive towards more accurate AFUE results while not greatly increasing the testing burden. (Busse, No. 22 at p. 10)

In the January 2016 Final Rule, DOE explained that industry stakeholders indicated that the current practice is typically to use the CO_2 percentage at the "top" of the manufacturer's specified range, and in some cases, even higher than that. Stakeholders provided data suggesting that the impacts on AFUE could be significant but variable[31], and there was also concern that some products may not feature any means of providing combustion setting adjustment. Finally, commenters indicated that DOE must evaluate the burden associated with potential re-testing should combustion setting specifications require manufacturers to re-rate their products. As discussed previously, DOE ultimately agreed that further study was needed on the impacts of the CO_2 percentage on AFUE and, therefore, declined to adopt the proposed amendments. 81 FR 2628, 2635-2636. Thus, there remained a lack of certainty regarding what settings would be most representative of field use.

DOE did not receive any information in response to the March 2022 NOPR that provided further clarity on this issue. Therefore, DOE has determined that it still lacks sufficient information to indicate that establishing a specification for excess air ratio, flue

[31] AHRI stated that the results of the testing of three residential boilers that it conducted at Intertek Testing Laboratories indicate that the proposed revised burner setup requirements change AFUE by 0.3 percent for each 1 percent difference in the CO_2 values. By contrast, Burnham stated that based on test data that it provided, for an oil-fired hot water boiler with an 11.5 to 12.5 percent CO_2 adjustment range in the I&O manual, DOE's proposed adjustment would reduce AFUE by as much as 1.0 percent compared to the rating under the existing test procedure. 81 FR 2628, 2636.

O_2 percentage, and/or flue CO_2 percentage would provide ratings that are more representative than the ratings provided under the current approach, and that doing so would not be unduly burdensome.

Therefore, DOE is maintaining the current instructions and is not establishing additional requirements specifying excess air ratio, flue O_2 percentage, and/or flue CO_2 percentage.

4. Supplemental Test Instructions

In the March 2022 NOPR, DOE responded to comments from BHI suggesting that DOE create a repository of supplemental test instructions, similar to that currently in place for commercial boilers,[32] instead of requiring a waiver to allow for use of specific test instructions not included in the I&O manual or the DOE test procedure. 87 FR 14622, 14635–14636. Specifically, BHI asserted that control systems are increasingly complex, which makes it impractical to run the test without special tools or codes, and that there are safety and reliability concerns with putting testing-specific instructions in the I&O manual. BHI also asserted that the use of the waiver process for these test instruction issues is burdensome, unnecessary, and inconsistent with the test procedure for commercial boilers.

In response, DOE noted that BHI did not provide specific examples of test instructions that would not be able to be included in the I&O manual due to concerns about safety or reliability, and that would thus need to be presented in a waiver. In

[32] For commercial boilers, DOE provides that a certification report may include supplemental testing instructions, if such information is necessary to run a valid test. Specifically, supplemental information must include any additional testing and testing set-up instructions (*e.g.*, specific operational or control codes or settings) which would be necessary to operate the basic model under the required conditions specified by the relevant test procedure. 10 CFR 429.60(b)(4).

addition, DOE noted it has not received any petitions for waiver for any basic models of consumer boilers, indicating there is not a problem with testing absent such additional information. Therefore, DOE did not propose to establish a repository for test instructions for consumer boilers and stated that if testing of a consumer boiler necessitates controls or instructions other than those included in the I&O manual, manufacturers may petition for a waiver under the process established at 10 CFR 430.27. DOE sought further comment on whether supplemental test instructions are necessary for consumer boilers. 87 FR 14622, 14636.

Rheem recommended that DOE use the I&O manual provided with the product as the primary instruction for testing a consumer boiler, and where a manufacturer participates in a third-party certification program (such as AHRI's) and declares supplemental instructions for product testing, the manufacturer should have the option to use such instructions for audit or enforcement testing. (Rheem, No. 18 at p. 5) A.O. Smith recommended that some supplemental instructions from manufacturers could ensure consistency in testing, such as the need to use the recirculation loop to prevent flashing in the heat exchanger or instructions to remove a water temperature sensor and plug the opening. (A.O. Smith, No. 24 at p. 5) Busse suggested that supplemental test instructions are necessary for minimum input rate adjustment (for step-modulating condensing boilers) and for steam boiler low water cutoff (wherein the feature periodically turns off the burner to monitor the settled water level and therefore prevents the boiler from operating continuously during a steady-state test). (Busse, No. 22 at p. 9)

As discussed in the March 2022 NOPR, DOE has not received any petitions for waivers for any basic models of consumer boilers, indicating there is not a problem with testing absent such additional information. Should testing of a consumer boiler

necessitate controls or instructions other than those included in the I&O manual, manufacturers may petition for a waiver under the process established at 10 CFR 430.27.

5. Input Rates for Step Modulating Boilers

Appendix N includes a number of specific provisions for consumer boilers with step modulating controls. Boilers with step modulating controls are capable of operating at reduced input rates (*i.e.*, less than that maximum nameplate input rate) and gradually or incrementally increasing or decreasing the input rate as needed to meet the heating load. The test procedure currently requires step modulating boilers to be tested at the maximum rate and the minimum (*i.e.*, reduced) input rate for the steady-state test (referencing section 9.1 of ANSI/ASHRAE 103-1993), the reduced input rate for the cool-down test (referencing section 9.5.2.4 of ANSI/ASHRAE 103-1993), and the reduced input rate for the heat-up test (referencing section 9.6.2.1 of ANSI/ASHRAE 103-1993). In addition, both the optional tracer gas test and the measurement of condensate under cyclic conditions, when conducted, are performed at the reduced input rate (referencing sections 9.7.5 and 9.8 of ANSI/ASHRAE 103-1993, respectively). ANSI/ASHRAE 103-2017 contains the same input rate requirements for modulating boilers as ANSI/ASHRAE 103-1993.

In the May 2020 RFI, DOE requested comment on whether the existing provisions for testing step modulating boilers appropriately reflect the performance of such boilers. If not, DOE sought specific recommendations on the changes that would be necessary to make the test procedure more representative for such products. 85 FR 29352, 29357. Commenters indicated these provisions were adequate, and DOE did not propose any amendments to the provisions for testing step modulating boilers in the March 2022 NOPR. 87 FR 14622, 14633.

In response to the March 2022 NOPR, BWC stated that it appreciated DOE not proposing that step modulating units account for operation at any additional input rates beyond those specified in the current test procedure. BWC stated that the test methods in ANSI/ASHRAE 103-2017 sufficiently measure the performance of these units at different input rates and are representative of a product's average use cycle. (BWC, No. 19, p. 4)

For the reasons discussed in the March 2022 NOPR, and in consideration of the comments received, DOE is not adopting any changes to the provisions for testing step modulating boilers in this final rule.

6. Return Water Temperature

The test procedure at appendix N currently requires a nominal return water temperature ("RWT") of 120 °F to 124 °F for non-condensing boilers and 120 °F ± 2 °F for condensing boilers (see section 7 of appendix N and sections 8.4.2.3 and 8.4.2.3.2 of ANSI/ASHRAE 103-1993, which are incorporated by reference).

In response to the May 2020 RFI, the CA IOUs requested that DOE consider adopting multiple RWTs in the amended test procedure for consumer boilers, consistent with the methodology being developed by the ASHRAE Standard 155P Committee for testing and rating commercial boilers, which requires testing at multiple RWTs depending on the operational characteristics of the boiler. As discussed in the March 2022 NOPR, DOE considers the impact of varying RWTs on field-installed efficiency in its energy conservation standards rulemakings. In the previous energy conservation standards rulemaking for consumer boilers, DOE developed AFUE adjustment factors for low, medium, and high RWT scenarios and estimated that, on average, AFUE would vary

from the rated value by ─ 2.66 percent to +3.15 percent depending on the model characteristics and RWT (*see* 81 FR 2320, 2354); however, DOE noted there is still a wide range of potential RWTs in the field. Thus, in the March 2022 NOPR, DOE sought additional comment on whether the RWT requirements in the current test method and ANSI/ASHRAE 103-2017 are representative and appropriate, and whether any specific changes to the required conditions could improve representativeness. DOE also sought comment on any associated test burden with changing RWTs. 87 FR 14622, 14633.

In response, the CA IOUs reiterated their request for DOE to review whether the 120 °F RWT requirement is appropriately representative of real-world operating conditions. (CA IOUs, No. 20 at p. 2)

AHRI and AGA & APGA urged DOE to align return water temperatures with those in ANSI/ASHRAE 103-2017. (AHRI, No. 26 at p. 3; AGA & APGA, No. 25 at p. 2)

BWC supported DOE's tentative conclusion of including the single return water temperature specified in ANSI/ASHRAE 103-2017 for ease of comparison between models and manufacturers. (BWC, No. 19 at p. 4) BWC asserted that a single condition would not increase the test burden. (BWC, No. 19 at p. 4)

A.O. Smith commented that the current return water temperature is representative of an average value for the wide range of operating temperatures in the field and indicated that requiring testing to multiple conditions may require adjustment of the standards. A.O. Smith added that non-condensing boilers are more likely to be installed in systems with higher supply and return water temperatures, and condensing boilers are more likely to be installed in systems with lower temperatures. (A.O. Smith, No. 24 at p.

3–4) A.O. Smith stated that testing at multiple water temperatures would add testing burden to a test that could already span two days to complete, and that the burden to retest and rerate products would also include updating heat output ratings and safety certifications. (*Id.*)

Rheem supported maintaining the return water temperature in the current test method, asserting that any change that could make the return water temperature more representative would be outweighed by the testing and certification burden on manufacturers. Specifically, Rheem noted that slight changes to the water temperature would not produce significantly more representative results, and major changes would require retesting of nearly all consumer boilers. (Rheem, No. 18 at p. 4)

Crown and U.S. Boiler supported the use of the water temperatures specified by ANSI/ASHRAE 103-2017 to reduce testing burden and complication. Crown and U.S. Boiler stated that a single set of water temperatures for all types of hot water boilers is appropriate to avoid consumer confusion, increased certification burden, and departure from the industry test method. Crown and U.S. Boiler added that changes to these water temperatures would cause significant changes in AFUE ratings for condensing boilers. (Crown, No. 16 at p. 3–4; U.S. Boiler, No. 17 at p. 3–4)

NYSERDA noted that return water temperature has a significant impact on boiler performance and urged DOE to incorporate return water temperatures that more accurately reflect real-world conditions. NYSERDA stated that the 120 °F return water temperature is too low, does not represent the boiler running conditions according to a research study done by The Electric and Gas Program Administrators of Massachusetts

Part of the Residential Evaluation Program Area in 2015,[33] and should be considered closer to 140 °F. NYSERDA claimed that the rationale for choosing the 120 °F return water temperature from 1978 is outdated and inconsistent with DOE's current test procedure methodologies for commercial HVAC equipment. NYSERDA recommended that DOE test at both 120 °F and 140 °F for return water temperatures but stated that if DOE had to test at only one temperature, it should be 140 °F. (NYSERDA, No. 23 at p. 2–4)

The Joint Advocates urged DOE to continue to investigate return water temperatures used in the test procedure to capture more representative performance, directing attention to data presented in appendix 7B to DOE's preliminary analysis technical support document ("TSD")[34], which indicated that there was an impact of return water temperature on the thermal efficiency[35] of a boiler. The Joint Advocates suggested that multiple temperatures (*i.e.*, 108 °F and 158 °F) would be more appropriate to be able to differentiate amongst different condensing boiler models, and that non-condensing boilers should be tested at a higher temperature of 158 °F. (Joint Advocates, No. 21 at p. 2-3)

Busse stated that the current RWT settings were from NBSIR 80-2110 and asserted that the underlying assumptions for the current return water temperature found in

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[33] High Efficiency Heating Equipment Impact Evaluation, Prepared for: The Electric and Gas Program Administrators of Massachusetts Part of the
Residential Evaluation Program Area, March 2015 at 22, available at *ma-eeac.org/wp-content/uploads/High-Efficiency-Heating-Equipment-Impact-Evaluation-Final-Report.pdf*.

[34] Appendix 7B of the preliminary analysis TSD is available at *www.regulations.gov* at Docket Number EERE-2019-BT-STD-0036. The data can be found in chapter 7B, page 11.

[35] Thermal efficiency for a commercial packaged boiler is determined using test procedures prescribed under 10 CFR 431.86 and is the ratio of the heat absorbed by the water or the water and steam to the higher heating value in the fuel burned. Data presented in the May 2022 Preliminary Analysis TSD reflected the performance of commercial packaged boilers due to the absence of information on consumer boilers.

NBSIR 80-2110, pages 1-2 are out of date or invalid.[36] Busse stated that the average distribution system water temperature in the current DOE test procedure should be closer to 133 °F based on heat load calculations to maintain a home at 65 °F. Busse noted that the current test procedure has an average distribution system water temperature of 130 °F (based on a return water temperature of 120 °F and an outlet temperature of 140 °F). However, Busse added that the average distribution system water temperature may be too high based on current or historically available heat distribution products, and that review literature from two cast-iron baseboard manufacturers and two finned-tube copper baseboard manufacturers suggest an average distribution system water temperature of 127 °F would be more representative. Busse stated that current industry practice for step-modulating, condensing boilers may not allow operation at the original 190 °F average boiler water temperature (200 °F supply) or deliver 140 °F supply temperature at the 42 °F average outdoor temperature at the default controller settings. (Busse, No. 22 at p. 2-4) Busse recommended that a separate test should be required for determining heating capacity using a 180 °F return supply water temperature (or the maximum supply temperature allowed by the control system, if less than 200 °F), or, alternatively, the current return water temperature could be used with consideration of sensible heat losses only in order to estimate the steady-state efficiency for a noncondensing operation at high return water temperatures. (Busse, No. 22 at p. 6) Busse also asserted that boilers with reported ratings of 95 percent or 96 percent AFUE have such ratings as a result of a flawed calculation in the current test procedure, which does not account for the portion of the season during which the boiler would operate in a non-condensing mode (due to

[36] Kelly, George E. and Kuklewicz, Mark E., NBSIR 80-2110: Recommended Testing and Calculation Procedures for Estimating the Seasonal Performance of Residential Condensing Furnaces and Boilers, National Bureau of Standards (Sponsored by U.S. Department of Energy), April 1981.

return water temperatures being higher than 120 °F in certain conditions). (Busse, No. 22 at p. 11-12)

As acknowledged by commenters, the specification of RWT has a substantive impact on the AFUE of boilers. Condensing boilers in particular achieve higher efficiency levels by extracting latent heat from the flue gases in addition to sensible heat (*i.e.*, the condensation of flue gases releases a substantial amount of energy into the water that is being heated). However, flue gases can condense only if the dew point temperature of the vapor is reached. If the return (inlet) water is hotter than this dew point temperature, then condensation of the flue gases cannot occur in the heat exchanger, and the boiler operates in a non-condensing mode, reducing AFUE.

In addition to the recommendations provided by commenters, DOE research indicates a range of RWTs in consumer applications. DOE is aware that many existing consumer boiler installations require the RWT to be 160 °F and some even as high as 180 °F.[37] However, as new applications such as radiant floor heating and heat pump boilers become more prevalent in the market, DOE recognizes that some new boilers may be installed in homes that require lower RWTs. In addition, condensing boilers in new installations would be subject to lower RWTs because radiant floor heating and hydronic air handler applications represent a substantial proportion of new hot water boiler installations.[38] DOE research indicates some installations have RWT conditions as low

[37] On May 4, 2022, DOE published in the *Federal Register* a notice of availability of the preliminary analysis for energy conservation standards for consumer boilers (the "May 2022 Preliminary Analysis"). 87 FR 26304. DOE provided a technical support document ("TSD") for the May 2022 Preliminary Analysis in the rulemaking docket. *Id*. In the energy use analysis of the May 2022 Preliminary Analysis TSD, DOE estimated that 90 percent of condensing boilers installed as replacements to non-condensing boilers would be subject to a higher RWT of 158 °F to 160 °F.

[38] In the May 2022 Preliminary Analysis, DOE estimated that condensing boilers in new installations (new constructions or new owners) would be subject to an average RWT of 108 °F. See Appendix 7B of the preliminary analysis TSD, available at: *www.regulations.gov/document/EERE-2019-BT-STD-0036-0021*.

as 85 °F in certain cases.[39] DOE notes that the midpoint of the range of RWTs observed through DOE's research (ranging between 85 °F and 160 °F) is 122 °F, which is reasonably close to the 120 °F condition specified in appendix N and the industry test procedures. Given these considerations, DOE has determined that testing a consumer boiler at a single "high" RWT, as suggested by the Joint Advocates, NYSERDA, and Busse, would be less representative than the conditions specified by the current test procedure.

DOE also acknowledges the concerns raised by manufacturers regarding the potential need to retest and recertify all consumer boilers if a new test condition were to be required in addition to the currently established 120 °F condition. EPCA requires DOE to establish test procedures that are reasonably designed to produce test results that measure energy efficiency of a consumer boiler during a representative average use cycle or period of use, as determined by the Secretary, and shall not be unduly burdensome to conduct. (42 U.S.C. 6293(b)(3)) Based on the considerations discussed in this section, DOE has determined that it lacks data and information to conclude that a different RWT (or multiple RWTs) would be more representative than the current RWT requirements such that it would justify the potential burden of such a change. Hence, in this final rule, DOE is finalizing its proposal from the March 2022 NOPR to incorporate by reference the test conditions in ANSI/ASHRAE 103-2017. Should additional data or information become available in the future, DOE would consider this topic again in a subsequent test procedure rulemaking.

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[39] *See*, for example: *www.barronheating.com/blog/the-book-on-radiant-heating-when-it-makes-sense-and-when-it-might-not/#:~:text=Radiant%2Dfloor%20heating%20systems%20typically,55%E2%80%9370%C2%B0C)*. (Last accessed on October 6, 2022)

7. Standby Mode and Off Mode Electrical Energy Consumption

As discussed in section I.A of this final rule, EPCA requires that DOE amend test procedures to include standby mode and off mode energy consumption, "taking into consideration the most current versions of Standards 62301 and 62087 of the International Electrotechnical Commission." (42 U.S.C. 6295(gg)(2)(A)) The DOE test method currently references IEC 62301 (Edition 2.0 2011-01), which provides instructions for measuring standby mode and off mode energy consumption. IEC 62301 provides several options for measuring the standby mode and off mode power consumption using either the "sampling method," "average reading method," or "direct meter reading method." Although these methods vary, if the standby or off mode consumption is stable, each method can be completed in under 1 hour, and the sampling method can be completed in as little as 15 minutes.

In the March 2022 NOPR, DOE tentatively determined that the provisions in IEC 62301 provide an appropriate representation of standby mode and off mode energy consumption of consumer boilers and are not unduly burdensome; hence DOE did not propose any changes. Because commenters responding to the May 2020 RFI recommended streamlining the procedure for determining standby mode and off mode energy consumption, in the March 2022 NOPR DOE requested further comment on whether a simplified approach for measuring standby mode and off mode electrical energy consumption is appropriate and would provide accurate, representative results that are comparable to those obtained with IEC 62301. 87 FR 14622, 14634.

In response, BWC commented that the standby mode and off mode test methods are appropriate and do not need to be amended at this time. (BWC, No. 19 at p. 4)

Rheem stated that the current approach for measuring standby and off mode electrical energy consumption is not overly burdensome and should be maintained. Rheem also recommended that DOE examine a combined AFUE metric that includes standby and off mode electrical energy use, asserting that an increase in standby and off mode energy use may be needed to accommodate an increase in overall efficiency, and thus a combined AFUE metric would provide for greater design flexibility. (Rheem, No. 18 at p. 4)

DOE considered an integrated AFUE metric ("$AFUE_I$") in a test procedure final rule published October 20, 2010 ("October 2010 Final Rule"), which established the standby mode and off mode electrical energy use metrics. 75 FR 64621, 64626-64627 (Oct. 20, 2010). In the October 2010 Final Rule, DOE explored the possibility of regulating $AFUE_I$; however, commenters objected that the approach would provide an ineffective basis for regulation, and thus it was not "technically feasible" to integrate AFUE with standby mode and off mode energy consumption. *Id*. Separate metrics were established because the magnitude of the standby mode and off mode energy consumption was very small compared to the active mode fuel consumption, and, as a result, it was not possible to discern different levels of standby and off mode power consumption (*i.e.*, $AFUE_I$ values were essentially identical to AFUE values). *Id*.

Neither Rheem nor other commenters have presented DOE with any information to suggest that the conclusions from the October 2010 Final Rule—specifically, that an integrated metric would not be technically feasible—are no longer applicable. Furthermore, DOE is not aware of any current industry-accepted test procedure that combines the current AFUE metric with the standby mode and off mode power

consumption metrics. For these reasons, DOE is not adopting any new provisions for a combined metric in this final rule.

A.O. Smith recommended eliminating the standby mode and off mode power consumption testing due to the little impact the associated power consumption has on the total efficiency of a consumer boiler (less than a fraction of one percent). A.O. Smith indicated that procuring the adequate equipment and instrumentation required for this testing is burdensome. A.O. Smith also commented that removing these requirements would afford manufacturers the opportunity to potentially add safety enhancements such as carbon monoxide sensors, which require a small heating element to prevent premature failure, as well as options for control displays and ways to reduce cycling losses. (A.O. Smith, No. 24 at p. 4) A.O. Smith recommended that if DOE were to keep the standby mode and off mode tests as part of the test procedure, the standby mode and off mode power consumption should be measured with a simple current measurement with a calibrated watt meter. (A.O. Smith, No. 24 at p. 6)

As discussed, EPCA requires that DOE include in its test procedures a method for measuring standby mode and off mode power consumption, unless technically infeasible. (42 U.S.C. 6295(gg)(2)(A)) Further, in doing so, EPCA requires that DOE must consider IEC Standard 62301 and IEC Standard 62087. (42 U.S.C. 6295(gg)(2)(A)) Section 4.4 of IEC 62301 provides instruction on selecting acceptable power measuring instrumentation by specifying power measurement uncertainty bounds, frequency response, and long-term averaging (integrating) requirements. DOE notes that if a calibrated watt meter is capable of meeting these requirements, then it may be used in accordance with section 4.4 of IEC 62301.

AHRI noted that standby mode and off mode power consumption should not count as a loss because all energy brought into the system provides useful resistive heat to the building. AHRI stated that similar logic is used to give electric boilers a rating of 100 percent efficiency. (AHRI, No. 26 at p. 3)

While electrical component power draws that dissipate small amounts of heat to the surroundings may contribute to useful heating to the building, the building does not always demand heating. During the cooling season, any heat dissipated would be counterproductive. Furthermore, not all boilers are located in conditioned spaces. In addition, as discussed previously, EPCA requires DOE to include in its test procedures a method for measuring standby mode and off mode power consumption. (42 U.S.C. 6295(gg)(2)(A)) For these reasons, DOE makes no change to its inclusion of standby mode and off mode power in this final rule.

In conclusion, DOE has determined that no changes to the standby mode and off mode test provisions are warranted. As such, the new appendix EE test procedure maintains the same test methods for measuring these metrics as specified in the current appendix N test procedure.

8. Full Fuel Cycle Efficiency

The full fuel cycle ("FFC") accounts for the energy consumed in extracting, processing, and transporting fuels. In the March 2022 NOPR, DOE responded to comments received in response to the May 2020 RFI requesting that DOE consider incorporating an FFC analysis into the test procedure in order to allow for direct comparisons between fossil fuel-fired systems and electric systems. 87 FR 14622, 14634. DOE responded that FFC is typically considered in energy conservation standards

rulemakings—not as a metric for representing product efficiency. *Id.* In the March 2022 NOPR, DOE maintained its previous conclusion from the January 2016 Final Rule that a mathematical adjustment to the test procedure to account for FFC is not appropriate because the mathematical adjustment to the site-based energy descriptor relies on information that is updated annually, which would require annual updating of the test method. *Id.*

In response to the March 2022 NOPR, BWC stated that the FFC efficiency and source efficiency analysis are not appropriate to include in the Federal test procedure. (BWC, No. 19, p. 4)

For the reasons discussed in the March 2022 NOPR, DOE maintains in this final rule its previous determination not to account for FFC in the consumer boiler test procedure.

9. Idle Losses

In the March 2022 NOPR, DOE responded to comments received in response to the May 2020 RFI requesting that DOE consider "idle losses" that are not captured in the AFUE metric. 87 FR 14622, 14628. Specifically, Energy Kinetics asserted that oversizing of boilers can lead to wasted energy to heat up the boiler but not contribute to the heating of the hydronic loop. In the March 2022 NOPR, DOE stated that EPCA (42 U.S.C. 6295(f)(3)(A)-(B)) requires hot water boilers to have an automatic means for adjusting water temperature, which limits idle losses. DOE indicated that idle losses could be further addressed in the determination of AFUE; however, there was insufficient data to propose amendments to the test procedure to do so. DOE sought further comment from interested parties on the topic. 87 FR 14622, 14628.

In response to the March 2022 NOPR, Rheem agreed with DOE's statement that the prescriptive design requirements in EPCA at 42 U.S.C. 6295(f)(3) effectively reduce idle losses in the field. Rheem noted that if idle losses, both electrical and fossil fuel, were fully accounted for in the AFUE metric, then a standard could be proposed that would not require separate design requirements. (Rheem, No. 18 at p. 5)

DOE has determined that there remains insufficient information to further address idle losses in this rulemaking as it pertains to the determination of AFUE in the new appendix EE test procedure for consumer boilers.

H. Alternative Efficiency Determination Methods

At 10 CFR 429.70, DOE includes provisions for alternative efficiency determination methods ("AEDMs"), which are computer modeling or mathematical tools that predict the performance of non-tested basic models. They are derived from mathematical models and engineering principles that govern the energy efficiency and energy consumption characteristics of a type of covered equipment. These computer modeling and mathematical tools, when properly developed, can provide a relatively straight-forward and reasonably accurate means to predict the energy usage or efficiency characteristics of a basic model of a given covered product or equipment and reduce the burden and cost associated with testing. 78 FR 79579, 79580 (Dec. 31, 2013; the "December 2013 AEDM Final Rule"). Where authorized by regulation, AEDMs enable manufacturers to rate and certify their basic models by using the projected energy use or energy efficiency results derived from these simulation models in lieu of testing. *Id*. at 78 FR 79580.

DOE does not currently authorize the use of AEDMs for consumer boilers, whereas DOE does authorize the use of AEDMs for commercial packaged boilers.[40] Manufacturers of consumer boilers (or furnaces more generally) are not authorized to use an AEDM to determine ratings for these products. However, manufacturers of cast-iron boilers may determine AFUE for models at a capacity other than the highest or lowest of the group of basic models having identical intermediate sections and combustion chambers through linear interpolation of data obtained for the smallest and largest capacity units of the family. *See* 10 CFR 429.18(a)(2)(iv)(A). These provisions already provide manufacturers with an alternative method of rating consumer boilers without testing every model, and this alternative method reduces manufacturer test burden.

In the March 2022 NOPR, DOE requested comment on whether AEDM provisions similar to those in place for commercial equipment would be necessary and appropriate for consumer boilers. 87 FR 14622, 14635.

A.O. Smith stated that adding an AEDM option for consumer boilers would be reasonable; however, there is greater value to have an AEDM for commercial products given that those models can be engineered to order. (A.O. Smith, No. 24 at p. 4) Busse indicated that the breadth of a product line with similar geometries and performance would not seem to justify an AEDM; however, an AEDM may be the only method to avoid testing each model. (Busse, No. 22 at p. 8)

[40] In the December 2013 AEDM Final Rule, DOE explained that the AEDM provisions extend to those products or equipment which "have expensive or highly-customized basic models." 78 FR 79579, 79580. The current AEDM provisions for commercial HVAC equipment (including commercial package boilers, for example) were in part the result of a negotiated rulemaking effort by the Appliance Standards and Rulemaking Federal Advisory Committee (ASRAC) in 2013. *Id.* Boilers designed for residential applications were not considered at the time. 78 FR 79579.

In consideration of these comments, as well as considerations discussed in the March 2022 NOPR (*see* 87 FR 14622, 14635), in this final rule, DOE concludes that manufacturer testing burden is alleviated by the linear interpolation provisions for cast-iron boilers, such that an AEDM for consumer boilers more broadly is not warranted at this time.

I. Certification Provisions for Cast-Iron Boilers

As discussed in the March 2022 NOPR, the certification provisions at 10 CFR 429.18(a)(2)(iv)(A) alleviate testing burden for cast-iron boilers, which are commonly constructed of identical cast-iron heat exchanger sections. Boilers of the same cast-iron product family are often constructed so that the heating capacity can be increased by adding more sections to the heat exchanger. When a product family is designed in this way, linear interpolation is accurate[41] to predict the performance of intermediately-sized boilers. The March 2022 NOPR sought data and other information that would demonstrate that using a linear interpolation method for heat exchanger materials other than cast-iron would produce representative test results. 87 FR 14622, 14635.

AHRI and AGA and APGA supported extending of the use of linear interpolation to heat exchanger materials other than cast-iron, stating that linear interpolation is a valid calculation method for these products, as proven by the current cast-iron allowance. (AHRI, No. 26 at p. 4; AGA and APGA, No. 25 at p. 2)

A.O. Smith supported use of the interpolation method for boilers with heat exchangers other than cast-iron, stating that its copper finned-tube boilers have a tray of

[41] Test data analyzed as part of the 1979 rulemaking which established these provisions showed that the annual fuel utilization efficiency, energy consumption, and estimated annual operating cost of sectional cast-iron boilers can be accurately predicted by a linear interpolation based on data obtained from units having the smallest and largest number of intermediate sections. 44 FR 22410, 22415 (April 13, 1979).

tubes that increase in length proportionate to input rate, are consistent in geometry, and have only incremental changes proportionate to input rate. A.O. Smith added that its Lochinvar brand models have seven input rates ranging from 45,000 Btu/h through 260,000 Btu/h and all perform near 84.0-percent AFUE. (A.O. Smith, No. 24 at p. 5)

Rheem did not support the use of linear interpolation for certification of consumer boilers beyond what is already allowed for cast-iron boilers, stating that interpolation produces less accurate results than results derived from actual tests. (Rheem, No. 18 at p. 4)

Busse did not support using a linear interpolation method for heat exchanger materials other than cast-iron. Busse asserted that any difference and/or non-proportionality in excess air, flue loading, and/or flue cross-sectional area could produce non-linear results, which is also why cast-iron units equipped with draft hoods, draft diverters, or induced draft systems are more prone to producing non-linear results. (Busse, No. 22 at p. 7-8)

Based on DOE's review of product literature, DOE has determined that heat exchangers made of different materials may not be constructed with identical additive components the way cast-iron sectional heat exchangers are constructed; hence, the linear interpolation method may be less viable for other heat exchanger materials. DOE notes that stakeholders commenting in support of using linear interpolation for materials other than cast-iron did not provide any data to demonstrate the viability of a linear interpolation method for other heat exchanger materials. Given the concerns raised by Rheem and Busse regarding the potential for non-linear results for intermediately-sized boilers with non-cast-iron heat exchangers, as well as DOE's review of product literature,

DOE has concluded that there is not enough information to substantiate such a provision at this time. Hence, in this final rule, DOE maintains that the linear interpolation AEDM method applies only to cast-iron boilers.

Additionally, Busse recommended the following clarifications for using linear interpolation: (1) clarify if interpolated values are derived from truncated or pre-truncated AFUE values of smallest and largest capacity units, (2) update 10 CFR part 429 to allow interpolation of heating capacity derived from unrounded $Effy_{SS}$ values of smallest and largest capacity units, and (3) require third-party test agencies to qualify AFUE and heating capacity on an "interpolated" model. (Busse, No. 22 at p. 7-8)

First, as discussed in section III.F.8, DOE has amended the certification requirements for AFUE in the July 2022 Certification Final Rule to require that AFUE must be rounded to the nearest tenth of a percentage point when this value is reported. 87 FR 43968. Thus, as of this final rule, truncation is no longer used to report AFUE. DOE is clarifying in this final rule, however, that manufacturers may use either the rounded or unrounded AFUE values of the smallest and largest capacity units for linear interpolation. DOE is making this determination based on the fact that the results of the linear interpolation would be minimally impacted by rounding AFUE to the nearest tenth of a percentage point, compared to using unrounded values.

Second, DOE notes that heating capacity (Q_{OUT}), which is calculated in the current test procedure as a function of steady-state efficiency ($Effy_{SS}$), is not required to be certified to DOE at this time, nor has DOE proposed to make this a requirement. Currently, manufacturers must certify the nameplate input rate (Q_{IN}), which is a separate

metric and not a function of $Effy_{SS}$. Hence, DOE is not updating the linear interpolation provisions to include heating capacity (Q_{OUT}).

Third, requiring third-party testing to qualify AFUE ratings derived using the linear interpolation method would eliminate the reduction in test burden achieved with the alternate linear interpolation approach. DOE notes, however, that it can conduct assessment or enforcement testing on consumer boiler models, and this process serves to verify ratings (*see* subpart C to 10 CFR part 429).

In conclusion, DOE has determined in this final rule not to amend the linear interpolation provisions for consumer boilers.

J. Effective and Compliance Dates

The effective date for the adopted test procedure amendment will be 30 days after publication of this final rule in the *Federal Register*. EPCA prescribes that all representations of energy efficiency and energy use, including those made on marketing materials and product labels, must be made in accordance with an amended test procedure, beginning 180 days after publication of the final rule in the *Federal Register*. (42 U.S.C. 6293©(2)) EPCA provides an allowance for individual manufacturers to petition DOE for an extension of the 180-day period if the manufacturer may experience undue hardship in meeting the deadline. (42 U.S.C. 6293(c)(3)) To receive such an extension, petitions must be filed with DOE no later than 60 days before the end of the 180-day period and must detail how the manufacturer will experience undue hardship. (*Id*.)

K. Test Procedure Costs

EPCA requires that test procedures proposed by DOE not be unduly burdensome to conduct. (42 U.S.C. 6293(b)(3))

In the March 2022 NOPR, DOE discussed that the amendments proposed to the test procedure for consumer boilers would be expected to have minimal impact on efficiency ratings such that manufacturers would not be required to retest and recertify ratings. 87 FR 14622, 14625, 14636. DOE also tentatively determined that the proposed amendments would not impact testing costs or increase burden. DOE requested feedback from stakeholders on these tentative determinations. *Id*.

A.O. Smith supported DOE's determination that the proposed incorporation by reference of ASHRAE 41.6-2014 will not increase testing burden. A.O. Smith also stated that DOE's estimate for third-party AFUE testing is reasonable and agreed that the proposed incorporation by reference of ANSI/ASHRAE 103-2017 is not unduly burdensome. (A.O. Smith, No. 24 at p. 5) A.O. Smith stated that although there may be fractional changes in the AFUE rating as a result of testing to the 2017 version, these should not necessitate retesting or rerating of any existing boilers. A.O. Smith also supported having a publicly available AFUE calculation tool to enhance consistency of results across the industry. (A.O. Smith, No. 24 at p. 3)

Rheem stated that the test costs under the proposed appendix EE test procedure are likely to remain similar to the current appendix N test procedure. (Rheem, No. 18 at p. 5)

AHRI stated that it previously commented that a move to ANSI/ASHRAE 103-2017 would not result in increased test burden; however, it had come to AHRI's attention

that there are manufacturers using automated programs that would incur an increased test burden. (AHRI, No. 26 at p. 4)

DOE understands that AHRI is referring to pre-programmed cycle times, which execute burner on and off functions at pre-determined times per the DOE test procedure. From DOE's own testing of the impact of cycle timings at a third-party lab using an automated program, DOE has determined that these parameters can be simple to re-program and that doing so would not constitute undue test burden. As discussed in section III.D.1.c, other commenters requested DOE to further investigate whether the update in cycle times would increase burden by requiring retesting. Based on test data indicating little variation in test results due to the update in cycle times, DOE has determined that the impact of these amendments on ratings would be minimal. With regard to providing a publicly available AFUE calculation tool, DOE provides test report templates on its certification website,[42] including a template for the consumer boiler test procedure.

For this final rule, DOE has evaluated the impacts on ratings resulting from its adoption of the test methods in the updated industry test standard, ANSI/ASHRAE 103-2017. These updates are discussed in detail in section III.D.1 of this final rule. Based on this review, DOE has determined that manufacturers will be able to rely on data generated under the current test procedure. As such, it is unlikely that retesting of consumer boilers would be required solely as a result of DOE's adoption of the finalized amendments to the test procedure. However, if a manufacturer were to retest a model using the amended test procedure as finalized, DOE estimates that the cost of performing the amended AFUE test at a third-party laboratory would be $3,600, the same as the cost

[42] Standardized test report templates are available online at: *www.energy.gov/eere/buildings/standardized-templates-reporting-test-results*

of performing the current AFUE test. This estimate represents an increase of $600 from the cost estimate in the March 2022 NOPR, to account for overall increases in laboratory testing fees.

IV. Procedural Issues and Regulatory Review

A. Review Under Executive Orders 12866 and 13563

Executive Order ("E.O.")12866, "Regulatory Planning and Review," as supplemented and reaffirmed by E.O. 13563, "Improving Regulation and Regulatory Review," 76 FR 3821 (Jan. 21, 2011), requires agencies, to the extent permitted by law, to (1) propose or adopt a regulation only upon a reasoned determination that its benefits justify its costs (recognizing that some benefits and costs are difficult to quantify); (2) tailor regulations to impose the least burden on society, consistent with obtaining regulatory objectives, taking into account, among other things, and to the extent practicable, the costs of cumulative regulations; (3) select, in choosing among alternative regulatory approaches, those approaches that maximize net benefits (including potential economic, environmental, public health and safety, and other advantages; distributive impacts; and equity); (4) to the extent feasible, specify performance objectives, rather than specifying the behavior or manner of compliance that regulated entities must adopt; and (5) identify and assess available alternatives to direct regulation, including providing economic incentives to encourage the desired behavior, such as user fees or marketable permits, or providing information upon which choices can be made by the public. DOE emphasizes as well that E.O. 13563 requires agencies to use the best available techniques to quantify anticipated present and future benefits and costs as accurately as possible. In its guidance, the Office of Information and Regulatory Affairs ("OIRA") in the Office of Management and Budget ("OMB") has emphasized that such techniques may include

identifying changing future compliance costs that might result from technological innovation or anticipated behavioral changes. For the reasons stated in the preamble, this final regulatory action is consistent with these principles.

Section 6(a) of E.O. 12866 also requires agencies to submit "significant regulatory actions" to OIRA for review. OIRA has determined that this final regulatory action does not constitute a "significant regulatory action" under section 3(f) of E.O. 12866. Accordingly, this action was not submitted to OIRA for review under E.O. 12866.

B. Review Under the Regulatory Flexibility Act

The Regulatory Flexibility Act (5 U.S.C. 601 *et seq*.) requires preparation of a final regulatory flexibility analysis (FRFA) for any final rule where the agency was first required by law to publish a proposed rule for public comment, unless the agency certifies that the rule, if promulgated, will not have a significant economic impact on a substantial number of small entities. As required by Executive Order 13272, "Proper Consideration of Small Entities in Agency Rulemaking," 67 FR 53461 (August 16, 2002), DOE published procedures and policies on February 19, 2003, to ensure that the potential impacts of its rules on small entities are properly considered during the DOE rulemaking process. 68 FR 7990. DOE has made its procedures and policies available on the Office of the General Counsel's website: *www.energy.gov/gc/office-general-counsel*.

DOE reviewed this final rule under the provisions of the Regulatory Flexibility Act and the procedures and policies published on February 19, 2003. DOE certifies that

this rule, if adopted, would not have significant economic impact on a substantial number of small entities. The factual basis of this certification is set forth below.

Under 42 U.S.C. 6293, EPCA sets forth the criteria and procedures DOE must follow when prescribing or amending test procedures for covered products. EPCA requires that any test procedures prescribed or amended under this section shall be reasonably designed to produce test results which measure energy efficiency, energy use, or estimated annual operating cost of a covered product during a representative average use cycle (as determined by the Secretary) or period of use and shall not be unduly burdensome to conduct. (42 U.S.C. 6293(b)(3))

EPCA also requires that, at least once every 7 years, DOE evaluate test procedures for each type of covered product, including consumer boilers, to determine whether amended test procedures would more accurately or fully comply with the requirements for the test procedures to not be unduly burdensome to conduct and be reasonably designed to produce test results that reflect energy efficiency, energy use, and estimated operating costs during a representative average use cycle or period of use. (42 U.S.C. 6293(b)(1)(A)) DOE is publishing this final rule in satisfaction of the 7-year review requirement specified in EPCA. (42 U.S.C. 6293(b)(1)(A))

DOE did not receive written comments that specifically addressed impacts on small businesses or that were provided in response to the March 2022 NOPR.

The Small Business Administration ("SBA") has set a size threshold, which defines those entities classified as "small businesses" for the purposes of the statute. DOE used the SBA's small business size standards to determine whether any small entities would be subject to the requirements of the rule. *See* 13 CFR part

121. The products covered by this rule are classified under North American Industry Classification System ("NAICS") code 333414,[43] "Heating Equipment (except Warm Air Furnaces) Manufacturing." In 13 CFR 121.201, the SBA sets a threshold of 500 employees or fewer for an entity to be considered as a small business for this category. This employment figure is enterprise-wide, encompassing employees at the parent, subsidiary, and sister corporations.

Consistent with the March 2022 NOPR, DOE relied on the Compliance Certification Database ("CCD")[44], the AHRI database,[45] the California Energy Commission's Modernized Appliance Efficiency Database System ("MAEDbS"),[46] the ENERGY STAR Product Finder database,[47] and the prior consumer boiler energy conservation standards rulemaking to create a list of companies that import or otherwise manufacture the products covered by this final rule. DOE used the publicly available information and subscription-based market research tools (*e.g.,* reports from Dun & Bradstreet[48]) to identify 27 original equipment manufacturers ("OEMs") affected by this final rule. Of the 27 OEMs, DOE identified five domestic OEMs of consumer boilers that met the SBA definition of a "small business" and are not foreign-owned and operated.

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[43] The SBA size standards (effective October 1, 2022) are listed by NAICS code and industry description and are available at: *www.sba.gov/document/support-table-size-standards* (last accessed on December 1, 2022).
[44] U.S. Department of Energy Compliance Certification Database, available at: *www.regulations.doe.gov/certification-data/products.html*.
[45] The AHRI Database is available at: *www.ahridirectory.org* (last accessed March 3, 2021).
[46] California Energy Commission's MAEDbS is available at *cacertappliances.energy.ca.*gov/*Pages/ApplianceSearch.aspx* (last accessed September 22, 2021).
[47] The ENERGY STAR Product Finder database is available at *energystar.gov/productfinder/* (last accessed September 22, 2021).
[48] D&B Hoovers | Company Information | Industry Information | Lists, *app.dnbhoovers.com/* (last accessed September 29, 2022).

In this final rule, DOE updates appendix N to remove the provisions applicable only to consumer boilers and to rename the current appendix as "Uniform Test Method for Measuring the Energy Consumption of Furnaces." Correspondingly, this final rule establishes a new test procedure at 10 CFR part 430 subpart B, appendix EE, "Uniform Test Method for Measuring the Energy Consumption of Boilers" ("appendix EE"). In the new appendix EE, DOE includes all provisions currently included in appendix N relevant to consumer boilers, with the following modifications:

(1) Incorporate by reference the current revision to the applicable industry standard, ANSI/ASHRAE 103-2017, "Methods of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnaces and Boilers."

(2) Incorporate by reference the current revision of ASTM Standard D2156-09 (Reapproved 2018), "Standard Test Method for Smoke Density in Flue Gases from Burning Distillate Fuels."

(3) Incorporate by reference ANSI/ASHRAE 41.6-2014, "Standard Method for Humidity Measurement."

(4) Update the definitions to reflect the changes in ANSI/ASHRAE 103-2017 as compared to ANSI/ASHRAE 103-1993.

(5) Provide corrections to erroneous calculations and add clarifications to test conditions and setup requirements.

DOE is also removing the definition of outdoor furnace or boiler from 10 CFR 430.2.

DOE has determined that the amendments adopted in this final rule will not substantively impact the measured efficiency of consumer boilers or require retesting or recertification solely as a result of DOE's adoption of the amendments to the test procedures. As outlined in Table II.1 of this final rule, the new appendix EE includes all provisions currently included in appendix N relevant to consumer boilers, with modifications to: harmonize with industry standard updates; provide corrections to erroneous calculations; and add clarifications to test conditions and setup requirements. Additionally, the update to use more representative cycle timings and oversize factors in the new appendix EE test procedure was demonstrated to have minimal impact on AFUE ratings as a result of testing. See section III.K of this final rule for additional details on test procedure costs. DOE also determined that the amendments would not increase the testing costs or burden associated with the DOE test procedure for consumer boilers, as the cost to test consumer boilers under the amended test procedure is $3,600, the same as the cost to test consumer boilers under the existing test procedure.

Therefore, DOE concludes that the cost effects accruing from the final rule would not have a "significant economic impact on a substantial number of small entities," and that the preparation of a FRFA is not warranted.

C. Review Under the Paperwork Reduction Act of 1995

Manufacturers of consumer boilers must certify to DOE that their products comply with any applicable energy conservation standards. To certify compliance, manufacturers must first obtain test data for their products according to the DOE test procedures, including any amendments adopted for those test procedures. DOE has established regulations for the certification and recordkeeping requirements for all covered consumer products and commercial equipment, including consumer boilers. (*See generally* 10 CFR part 429.) The collection-of-information requirement for the

certification and recordkeeping is subject to review and approval by OMB under the Paperwork Reduction Act (PRA). This requirement has been approved by OMB under OMB control number 1910-1400. Public reporting burden for the certification is estimated to average 35 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information.

DOE is not amending the certification or reporting requirements for consumer boilers in this final rule.

Notwithstanding any other provision of the law, no person is required to respond to, nor shall any person be subject to a penalty for failure to comply with, a collection of information subject to the requirements of the PRA, unless that collection of information displays a currently valid OMB Control Number.

D. Review Under the National Environmental Policy Act of 1969

In this final rule, DOE establishes test procedure amendments that it expects will be used to develop and implement future energy conservation standards for consumer boilers. DOE has determined that this rule falls into a class of actions that are categorically excluded from review under the National Environmental Policy Act of 1969 (42 U.S.C. 4321 *et seq*.) and DOE's implementing regulations at 10 CFR part 1021. Specifically, DOE has determined that adopting test procedures for measuring energy efficiency of consumer products and industrial equipment is consistent with activities identified in 10 CFR part 1021, appendix A to subpart D, A5 and A6. Accordingly, neither an environmental assessment nor an environmental impact statement is required.

E. Review Under Executive Order 13132

Executive Order 13132, "Federalism," 64 FR 43255 (August 4, 1999), imposes certain requirements on agencies formulating and implementing policies or regulations that preempt State law or that have federalism implications. The Executive order requires agencies to examine the constitutional and statutory authority supporting any action that would limit the policymaking discretion of the States and to carefully assess the necessity for such actions. The Executive order also requires agencies to have an accountable process to ensure meaningful and timely input by State and local officials in the development of regulatory policies that have federalism implications. On March 14, 2000, DOE published a statement of policy describing the intergovernmental consultation process it will follow in the development of such regulations. 65 FR 13735. DOE examined this final rule and determined that it will not have a substantial direct effect on the States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among the various levels of government. EPCA governs and prescribes Federal preemption of State regulations as to energy conservation for the products that are the subject of this final rule. States can petition DOE for exemption from such preemption to the extent, and based on criteria, set forth in EPCA. (42 U.S.C. 6297(d)) No further action is required by Executive Order 13132.

F. Review Under Executive Order 12988

Regarding the review of existing regulations and the promulgation of new regulations, section 3(a) of Executive Order 12988, "Civil Justice Reform," 61 FR 4729 (Feb. 7, 1996), imposes on Federal agencies the general duty to adhere to the following requirements: (1) eliminate drafting errors and ambiguity; (2) write regulations to minimize litigation; (3) provide a clear legal standard for affected conduct rather than a general standard; and (4) promote simplification and burden reduction. Section 3(b) of

Executive Order 12988 specifically requires that executive agencies make every reasonable effort to ensure that the regulation: (1) clearly specifies the preemptive effect, if any; (2) clearly specifies any effect on existing Federal law or regulation; (3) provides a clear legal standard for affected conduct while promoting simplification and burden reduction; (4) specifies the retroactive effect, if any; (5) adequately defines key terms; and (6) addresses other important issues affecting clarity and general draftsmanship under any guidelines issued by the Attorney General. Section 3(c) of Executive Order 12988 requires Executive agencies to review regulations in light of applicable standards in sections 3(a) and 3(b) to determine whether they are met or it is unreasonable to meet one or more of them. DOE has completed the required review and determined that, to the extent permitted by law, this final rule meets the relevant standards of Executive Order 12988.

G. Review Under the Unfunded Mandates Reform Act of 1995

Title II of the Unfunded Mandates Reform Act of 1995 ("UMRA") requires each Federal agency to assess the effects of Federal regulatory actions on State, local, and Tribal governments and the private sector. Pub. L. 104-4, sec. 201 (codified at 2 U.S.C. 1531). For a regulatory action resulting in a rule that may cause the expenditure by State, local, and Tribal governments, in the aggregate, or by the private sector, of $100 million or more in any one year (adjusted annually for inflation), section 202 of UMRA requires a Federal agency to publish a written statement that estimates the resulting costs, benefits, and other effects on the national economy. (2 U.S.C. 1532(a), (b)) The UMRA also requires a Federal agency to develop an effective process to permit timely input by elected officers of State, local, and Tribal governments on a proposed "significant intergovernmental mandate," and requires an agency plan for giving notice and opportunity for timely input to potentially affected small governments before establishing

any requirements that might significantly or uniquely affect small governments. On March 18, 1997, DOE published a statement of policy on its process for intergovernmental consultation under UMRA. 62 FR 12820; also available at *energy.gov/gc/office-general-counsel*. DOE examined this final rule according to UMRA and its statement of policy and determined that the rule contains neither an intergovernmental mandate, nor a mandate that may result in the expenditure of $100 million or more in any year, so these requirements do not apply.

H. Review Under the Treasury and General Government Appropriations Act, 1999

Section 654 of the Treasury and General Government Appropriations Act, 1999 (Pub. L. 105-277) requires Federal agencies to issue a Family Policymaking Assessment for any rule that may affect family well-being. This final rule will not have any impact on the autonomy or integrity of the family as an institution. Accordingly, DOE has concluded that it is not necessary to prepare a Family Policymaking Assessment.

I. Review Under Executive Order 12630

DOE has determined, under Executive Order 12630, "Governmental Actions and Interference with Constitutionally Protected Property Rights," 53 FR 8859 (March 18, 1988), that this regulation will not result in any takings that might require compensation under the Fifth Amendment to the U.S. Constitution.

J. Review Under Treasury and General Government Appropriations Act, 2001

Section 515 of the Treasury and General Government Appropriations Act, 2001 (44 U.S.C. 3516 note) provides for agencies to review most disseminations of information to the public under guidelines established by each agency pursuant to general guidelines issued by OMB. OMB's guidelines were published at 67 FR 8452 (Feb. 22,

2002), and DOE's guidelines were published at 67 FR 62446 (Oct. 7, 2002). Pursuant to OMB Memorandum M-19-15, Improving Implementation of the Information Quality Act (April 24, 2019), DOE published updated guidelines which are available at *energy.gov/sites/prod/files/2019/12/f70/DOE%20Final%20Updated%20IQA%20Guidelines%20Dec%202019.pdf*. DOE has reviewed this final rule under the OMB and DOE guidelines and has concluded that it is consistent with applicable policies in those guidelines.

K. Review Under Executive Order 13211

Executive Order 13211, "Actions Concerning Regulations That Significantly Affect Energy Supply, Distribution, or Use," 66 FR 28355 (May 22, 2001), requires Federal agencies to prepare and submit to OMB, a Statement of Energy Effects for any significant energy action. A "significant energy action" is defined as any action by an agency that promulgated or is expected to lead to promulgation of a final rule, and that: (1) is a significant regulatory action under Executive Order 12866, or any successor order; and (2) is likely to have a significant adverse effect on the supply, distribution, or use of energy; or (3) is designated by the Administrator of OIRA as a significant energy action. For any significant energy action, the agency must give a detailed statement of any adverse effects on energy supply, distribution, or use if the regulation is implemented, and of reasonable alternatives to the action and its expected benefits on energy supply, distribution, and use.

This regulatory action is not a significant regulatory action under Executive Order 12866. Moreover, it would not have a significant adverse effect on the supply, distribution, or use of energy, nor has it been designated as a significant energy action by

the Administrator of OIRA. Therefore, it is not a significant energy action, and, accordingly, DOE has not prepared a Statement of Energy Effects.

L. Review Under Section 32 of the Federal Energy Administration Act of 1974

Under section 301 of the Department of Energy Organization Act (Pub. L. 95–91; 42 U.S.C. 7101), DOE must comply with section 32 of the Federal Energy Administration Act of 1974, as amended by the Federal Energy Administration Authorization Act of 1977. (15 U.S.C. 788; "FEAA") Section 32 essentially provides in relevant part that, where a proposed rule authorizes or requires use of commercial standards, the notice of proposed rulemaking must inform the public of the use and background of such standards. In addition, section 32(c) requires DOE to consult with the Attorney General and the Chairman of the Federal Trade Commission ("FTC") concerning the impact of the commercial or industry standards on competition.

The modifications to the test procedure for consumer boilers adopted in this final rule incorporates testing methods contained in certain sections of the following commercial standards: ASHRAE Standard 103-2017, ASTM D2156-09 (R2018), and ASHRAE Standard 41.6-2014. DOE has evaluated these standards and is unable to conclude whether it fully complies with the requirements of section 32(b) of the FEAA (*i.e.*, whether it was developed in a manner that fully provides for public participation, comment, and review.) DOE has consulted with both the Attorney General and the Chairman of the FTC about the impact on competition of using the methods contained in these standards and has received no comments objecting to their use.

M. Congressional Notification

As required by 5 U.S.C. 801, DOE will report to Congress on the promulgation of this rule before its effective date. The report will state that it has been determined that the rule is not a "major rule" as defined by 5 U.S.C. 804(2).

N. Description of Materials Incorporated by Reference

ASHRAE 103-2017 is an industry accepted test standard that provides procedures for determining the annual fuel utilization efficiency of consumer furnaces and boilers. Specifically, the test procedure codified by this final rule references sections of ASHRAE 103-2017 for definitions, classifications, requirements, instruments, methods of testing, testing procedures, nomenclature, and calculations for determining the AFUE of consumer boilers.

ASHRAE 41.6-2014 is an industry accepted test standard that includes instructions for measuring the relative humidity of test chamber air. Specifically, the test procedure codified by this final rule references sections of ASHRAE 103-2017 that in turn reference ASHRAE 41.6-2014 for air humidity measurement instructions.

These test standards are all readily available from ANSI (*webstore.ansi.org*) or ASHRAE (*www.ashrae.org*).

ASTM D2156-09 (R2018) is an industry accepted test standard that includes instructions for determining the amount of smoke produced by an oil burner to ensure the burner is adjusted properly. Specifically, the test procedure codified by this final rule references sections of ASTM D2156-09 (R2018) for these instructions.

This test standard is readily available from ASTM International (*www.astm.org*).

IEC 62301 is an industry-accepted test procedure for measuring standby mode and off mode energy consumption. The test procedure codified by this final rule references IEC 62301 for performing the standby mode and off mode power measurements for consumer boilers. This test standard is readily available from IEC (*webstore.iec.ch).*

The following standards included in the regulatory text were previously approved for incorporation by reference for the locations in which they appear in this final rule: ANSI/ASHRAE 103-1993, and ASTM D2156-09 (Reapproved 2013).

V. Approval of the Office of the Secretary

The Secretary of Energy has approved publication of this final rule.

List of Subjects

10 CFR Part 429

Administrative practice and procedure, Confidential business information, Energy conservation, Household appliances, Imports, Intergovernmental relations, Reporting and recordkeeping requirements, Small businesses.

10 CFR Part 430

Administrative practice and procedure, Confidential business information, Energy conservation, Household appliances, Imports, Incorporation by reference, Intergovernmental relations, Small businesses.

Signing Authority

This document of the Department of Energy was signed on February 21, 2023, by Francisco Alejandro Moreno, Acting Assistant Secretary for Energy Efficiency and Renewable Energy. That document with the original signature and date is maintained by

DOE. For administrative purposes only, and in compliance with requirements of the Office of the Federal Register, the undersigned DOE Federal Register Liaison Officer has been authorized to sign and submit the document in electronic format for publication, as an official document of the Department of Energy. This administrative process in no way alters the legal effect of this document upon publication in the *Federal Register*.

Signed in Washington, DC, on February 22, 2023.

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Treena V. Garrett
Federal Register Liaison Officer,
U.S. Department of Energy

For the reasons stated in the preamble, DOE amends parts 429 and 430 of chapter II of title 10, Code of Federal Regulations as set forth below:

PART 429 – CERTIFICATION COMPLIANCE AND ENFORCEMENT FOR CONSUMER PRODUCTS AND COMMERCIAL AND INDUSTRIAL EQUIPMENT

1. The authority citation for part 429 continues to read as follows:

Authority: 42 U.S.C. 6291-6317; 28 U.S.C. 2461 note.

§429.134 [Amended]

2. Section 429.134 is amended by:

a. In paragraph (h) introductory text, removing the words “appendix N” and adding in their place the word “appendix EE”;

b. In paragraph (h)(1)(i)(A), removing the words “section 6 of appendix N” and adding in their place the words “section 6 of appendix EE”; and

c. In paragraph (h)(2)(i)(A), removing the words “appendix N” and adding in their place the words “appendix EE”.

PART 430 – ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS

3. The authority citation for part 430 continues to read as follows:

Authority: 42 U.S.C. 6291-6309; 28 U.S.C. 2461 note.

§430.2 [Amended]

4. Section 430.2 is amended by removing the definition of “Outdoor furnace or boiler”.

5. Section 430.3 is amended by:

a. In paragraph (g)(11), removing the words “appendix F” and adding in their place the words “appendices F and EE”;

b. In paragraph (g)(17), removing the words “appendix O” and adding in their place the words “§ 430.23 and appendices O and EE”;

c. Revising paragraph (j) introductory text;

d. In paragraph (j)(3), removing the words “appendix O” and adding in their place the words “appendices O and EE”; and

e. In paragraph (p)(7), removing the text “CC, and FF” and adding in their place “CC, EE, and FF”.

The revision reads as follows:

§430.3 Materials incorporated by reference.

* * * * *

(j) *ATSM*. ASTM International, 100 Barr Harbor Drive, Post Office Box C700, West Conshohocken, PA 19428-2959, (877) 909-2786, *www.astm.org.*

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6. Section 430.23 is amended by revising paragraph (n) to read as follows:

§430.23 Test Procedures for the measurement of energy and water consumption.

* * * * *

(n) *Furnaces*. (1) The estimated annual operating cost for furnaces is the sum of:

(i) The product of the average annual fuel energy consumption, in Btu's per year for gas or oil furnaces or in kilowatt-hours per year for electric furnaces, determined according to section 10.2.2 or 10.3 of appendix N of this subpart, respectively, (for furnaces, excluding low pressure steam or hot water boilers and electric boilers) or section 10.2.2 or 10.3 of appendix EE of this subpart, respectively (for low pressure steam or hot water boilers and electric boilers), and the representative average unit cost in dollars per Btu for gas or oil, or dollars per kilowatt-hour for electric, as appropriate, as provided pursuant to section 323(b)(2) of the Act; plus

(ii) The product of the average annual auxiliary electric energy consumption in kilowatt-hours per year determined according to section 10.2.3 of appendix N of this subpart (for furnaces, excluding low pressure steam or hot water boilers and electric boilers) or section 10.2.3 of appendix EE of this subpart (for low pressure steam or hot water boilers and electric boilers) of this subpart, and the representative average unit cost in dollars per kilowatt-hour as provided pursuant to section 323(b)(2) of the Act.

(iii) Round the resulting sum to the nearest dollar per year.

(2) The annual fuel utilization efficiency (AFUE) for furnaces, expressed in percent, is the ratio of the annual fuel output of useful energy delivered to the heated space to the annual fuel energy input to the furnace.

(i) For gas and oil furnaces, determine AFUE according to section 10.1 of appendix N (for furnaces, excluding low pressure steam or hot water boilers and electric boilers) or section 10.1 of appendix EE (for low pressure steam or hot water boilers and electric boilers) of this subpart, as applicable.

(ii) For electric furnaces, excluding electric boilers, determine AFUE in accordance with section 11.1 of ANSI/ASHRAE 103-1993 (incorporated by reference, *see* § 430.3); for electric boilers, determine AFUE in accordance with section 11.1 of ANSI/ASHRAE 103-2017 (incorporated by reference, *see* § 430.3).

(iii) Round the AFUE to one-tenth of a percentage point.

(3) The estimated regional annual operating cost for furnaces is calculated as follows:

(i) When using appendix N of this subpart for furnaces excluding low pressure steam or hot water boilers and electric boilers (see the note at the beginning of appendix N of this subpart),

(A) For gas or oil-fueled furnaces,

$$(E_{FR} \times C_{BTU}) + (E_{AER} \times C_{KWH})$$

Where:

E_{FR} = the regional annual fuel energy consumption in Btu per year, determined according to section 10.7.1 of appendix N of this subpart;

C_{BTU} = the representative average unit cost in dollars per Btu of gas or oil, as provided pursuant to section 323(b)(2) of the Act;

E_{AER} = the regional annual auxiliary electrical energy consumption in kilowatt-hours per year, determined according to section 10.7.2 of appendix N of this subpart; and

C_{KWH} = the representative average unit cost in dollars per kilowatt-hour of electricity, as provided pursuant to section 323(b)(2) of the Act.

(B) For electric furnaces,

$$(E_{ER} \times C_{KWH})$$

Where:

E_{ER} = the regional annual fuel energy consumption in kilowatt-hours per year, determined according to section 10.7.3 of appendix N of this subpart; and

C_{KWH} is as defined in paragraph (n)(3)(i)(A) of this section.

(ii) When using appendix EE of this subpart for low pressure steam or hot water boilers and electric boilers (see the note at the beginning of appendix EE of this subpart),

(A) For gas or oil-fueled boilers,

$$(E_{FR} \times C_{BTU}) + (E_{AER} \times C_{KWH})$$

Where:

E_{FR} = the regional annual fuel energy consumption in Btu per year, determined according to section 10.5.1 of appendix EE of this subpart;

C_{BTU} and C_{KWH} are as defined in paragraph (n)(3)(i)(A) of this section; and

E_{AER} = the regional annual auxiliary electrical energy consumption in kilowatt-hours per year, determined according to section 10.5.2 of appendix EE of this subpart.

(B) For electric boilers,

$$(E_{ER} \times C_{KWH})$$

Where:

E_{ER} = the regional annual fuel energy consumption in kilowatt-hours per year, determined according to section 10.5.3 of appendix EE of this subpart; and

C_{KWH} is as defined in paragraph (n)(3)(i)(A) of this section.

(iii) Round the estimated regional annual operating cost to the nearest dollar per year.

(4) The energy factor for furnaces, expressed in percent, is the ratio of annual fuel output of useful energy delivered to the heated space to the total annual energy input to the furnace determined according to either section 10.6 of appendix N of this subpart (for furnaces, excluding low pressure steam or hot water boilers and electric boilers) or section 10.4 of appendix EE of this subpart (for low pressure steam or hot water boilers and electric boilers), as applicable.

(5) The average standby mode and off mode electrical power consumption for furnaces shall be determined according to section 8.10 of appendix N of this subpart (for furnaces, excluding low pressure steam or hot water boilers and electric boilers) or section 8.9 of appendix EE of this subpart (for low pressure steam or hot water boilers and electric boilers), as applicable. Round the average standby mode and off mode electrical power consumption to the nearest tenth of a watt.

(6) Other useful measures of energy consumption for furnaces shall be those measures of energy consumption which the Secretary determines are likely to assist consumers in making purchasing decisions and which are derived from the application of appendix N of this subpart (for furnaces, excluding low pressure steam or hot water boilers and electric boilers) or appendix EE of this subpart (for low pressure steam or hot water boilers and electric boilers).

* * * * *

7. Appendix N to subpart B of part 430 is revised to read as follows:

Appendix N to Subpart B of Part 430—Uniform Test Method for Measuring the Energy Consumption of Consumer Furnaces Other Than Boilers

0. Incorporation by reference

DOE incorporated by reference in §430.3, the entire standards for ASTM D2156R13 and IEC 62301. DOE also incorporated selected provisions of ASHRAE 103-1993.

1. *Scope*. The scope of this appendix is as specified in section 2 of ASHRAE 103-1993 as it pertains to furnaces other than low pressure steam or hot water boilers or to electric boilers. Low pressure steam or hot water boilers and electric boilers are addressed in appendix EE of this subpart.

2. *Definitions*. Definitions include those specified in section 3 of ASHRAE 103-1993 and the following additional and modified definitions.

Active mode means the condition in which the furnace is connected to the power source, and at least one of the burner, electric resistance elements, or any electrical auxiliaries such as blowers, are activated.

Control means a device used to regulate the operation of a piece of equipment and the supply of fuel, electricity, air, or water.

Draft inducer means a fan incorporated in the furnace that either draws or forces air into the combustion chamber.

Gas valve means an automatic or semi-automatic device consisting essentially of a valve and operator that controls the gas supply to the burner(s) during normal operation of an

appliance. The operator may be actuated by application of gas pressure on a flexible diaphragm, by electrical means, by mechanical means or by other means.

Installation and operation (I&O) manual means instructions for installing, commissioning, and operating the furnace, which are supplied with the product when shipped by the manufacturer.

Isolated combustion system means a system where a unit is installed within the structure, but isolated from the heated space. A portion of the jacket heat from the unit is lost, and air for ventilation, combustion and draft control comes from outside the heated space.

Multi-position furnace means a furnace that can be installed in more than one airflow configuration (*i.e.,* upflow or horizontal; downflow or horizontal; upflow or downflow; and upflow, or downflow, or horizontal).

Off mode means a mode in which the furnace is connected to a mains power source and is not providing any active mode or standby mode function, and where the mode may persist for an indefinite time. The existence of an off switch in off position (a disconnected circuit) is included within the classification of off mode.

Off switch means the switch on the furnace that, when activated, results in a measurable change in energy consumption between the standby and off modes.

Oil control valve means an automatically or manually operated device consisting of an oil valve for controlling the fuel supply to a burner to regulate burner input.

Standby mode means any mode in which the furnace is connected to a mains power source and offers one or more of the following space heating functions that may persist:

(a) Activation of other modes (including activation or deactivation of active mode) by remote switch (including thermostat or remote control), internal or external sensors, and/or timer; and

(b) Continuous functions, including information or status displays or sensor-based functions.

Thermal stack damper means a type of stack damper that relies exclusively upon the changes in temperature in the stack gases to open or close the damper.

3. *Classifications*. Classifications are as specified in section 4 of ASHRAE 103-1993 for furnaces.

4. *Requirements*. Requirements are as specified in section 5 of ASHRAE 103-1993 for furnaces.

5. *Instruments*. Instruments must be as specified in section 6 of ASHRAE 103-1993.

6. *Apparatus*. The apparatus used in conjunction with the furnace during the testing must be as specified in section 7 of ASHRAE 103-1993 (except for the excluded sub-sections as enumerated at § 430.3(g)(15)); and as specified in sections 6.1 through 6.5 of this appendix.

6.1 *General*.

(a) Install the furnace in the test room in accordance with the I&O manual, as defined in section 2.6 of this appendix, except that if provisions within this appendix are specified, then the provisions herein drafted and prescribed by DOE govern. If the I&O manual and any additional provisions of this appendix are not sufficient for testing a furnace, the manufacturer must request a waiver from the test procedure pursuant to § 430.27.

(b) If the I&O manual indicates the unit should not be installed with a return duct, then the return (inlet) duct specified in section 7.2.1 of ASHRAE 103-1993 is not required.

(c) Test multi-position furnaces in the least efficient configuration. Testing of multi-position furnaces in other configurations is permitted if energy use or efficiency is represented pursuant to the requirements in 10 CFR part 429.

(d) The apparatuses described in section 6 of this appendix are used in conjunction with the furnace during testing. Each piece of apparatus shall conform to material and construction specifications listed in this appendix and in ASHRAE 103-1993, and the reference standards cited in this appendix and in ASHRAE 103-1993.

(e) Test rooms containing equipment must have suitable facilities for providing the utilities (including but not limited to environmental controls, applicable measurement equipment, and any other technology or tools) necessary for performance of the test and must be able to maintain conditions within the limits specified in section 6 of this appendix.

6.2 *Forced-air central furnaces (direct vent and direct exhaust)*.

(a) Units not equipped with a draft hood or draft diverter must be provided with the minimum-length vent configuration recommended in the I&O manual or a 5-ft flue pipe if there is no recommendation provided in the I&O manual (*see* Figure 4 of ASHRAE 103-1993). For a direct exhaust system, insulate the minimum-length vent configuration or the 5-ft flue pipe with insulation having an R-value not less than 7 and an outer layer of aluminum foil. For a direct vent system, *see* section 7.5 of ASHRAE 103-1993 for insulation requirements.

(b) For units with power burners, cover the flue collection box with insulation having an R-value of not less than 7 and an outer layer of aluminum foil before the cool-down and heat-up tests described in sections 9.5 and 9.6 of ASHRAE 103-1993, respectively. However, do not apply the insulation for the jacket loss test (if conducted) described in section 8.6 of ASHRAE 103-1993 or the steady-state test described in section 9.1 of ASHRAE 103-1993.

(c) For power-vented units, insulate the shroud surrounding the blower impeller with insulation having an R-value of not less than 7 and an outer layer of aluminum foil before the cool-down and heat-up tests described in sections 9.5 and 9.6, respectively, of ASHRAE 103-1993. However, do not apply the insulation for the jacket loss test (if conducted) described in section 8.6 of ASHRAE 103-1993 or the steady-state test described in section 9.1 of ASHRAE 103-1993. Do not insulate the blower motor or block the airflow openings that facilitate the cooling of the combustion blower motor or bearings.

6.3 *Downflow furnaces*. Install an internal section of vent pipe the same size as the flue collar for connecting the flue collar to the top of the unit, if not supplied by the manufacturer. However, do not insulate the internal vent pipe during the jacket loss test (if conducted) described in section 8.6 of ASHRAE 103-1993 or the steady-state test described in section 9.1 of ASHRAE 103-1993. Do not insulate the internal vent pipe before the cool-down and heat-up tests described in sections 9.5 and 9.6, respectively, of ASHRAE 103-1993. If the vent pipe is surrounded by a metal jacket, do not insulate the metal jacket. Install a 5-ft test stack of the same cross-sectional area or perimeter as the vent pipe above the top of the furnace. Tape or seal around the junction connecting the vent pipe and the 5-ft test stack. Insulate the 5-ft test stack with insulation having an R-

value not less than 7 and an outer layer of aluminum foil. (*See* Figure 3-E of ASHRAE 103-1993.)

6.4 *Units with draft hoods or draft diverters*. Install the stack damper in accordance with the I&O manual. Install 5 feet of stack above the damper.

(a) For units with an integral draft diverter, cover the 5-ft stack with insulation having an R-value of not less than 7 and an outer layer of aluminum foil.

(b) For units with draft hoods, insulate the flue pipe between the outlet of the furnace and the draft hood with insulation having an R-value of not less than 7 and an outer layer of aluminum foil.

(c) For units with integral draft diverters that are mounted in an exposed position (not inside the overall unit cabinet), cover the diverter boxes (excluding any openings through which draft relief air flows) before the beginning of any test (including jacket loss test) with insulation having an R-value of not less than 7 and an outer layer of aluminum foil.

(d) For units equipped with integral draft diverters that are enclosed within the overall unit cabinet, insulate the draft diverter box with insulation as described in section 6.4.c before the cool-down and heat-up tests described in sections 9.5 and 9.6, respectively, of ASHRAE 103-1993. However, do not apply the insulation for the jacket loss test (if conducted) described in section 8.6 of ASHRAE 103-1993 or the steady-state test described in section 9.1 of ASHRAE 103-1993.

6.5 *Condensate collection*. Attach condensate drain lines to the unit as specified in the I&O manual. Maintain a continuous downward slope of drain lines from the unit. Additional precautions (such as eliminating any line configuration or position that would otherwise restrict or block the flow of condensate or checking to ensure a proper

connection with condensate drain spout that allows for unobstructed flow) must be taken to facilitate uninterrupted flow of condensate during the test. Collection containers must be glass or polished stainless steel to facilitate removal of interior deposits. The collection container must have a vent opening to the atmosphere.

7. *Testing conditions*. The testing conditions must be as specified in section 8 of ASHRAE 103-1993 (except for the excluded sub-sections as enumerated at § 430.3(g)(15)); and as specified in sections 7.1 to 7.9 of this appendix, respectively.

7.1 *Fuel supply, gas*. In conducting the tests specified herein, gases with characteristics as shown in Table 1 of ASHRAE 103-1993 shall be used. Maintain the gas supply, ahead of all controls for a furnace, at a test pressure between the normal and increased values shown in Table 1 of ASHRAE 103-1993. Maintain the regulator outlet pressure at a level approximating that recommended in the I&O manual, as defined in section 2.6 of this appendix, or, in the absence of such recommendation, to the nominal regulator settings used when the product is shipped by the manufacturer. Use a gas having a specific gravity as shown in Table 1 of ASHRAE 103-1993 and with a higher heating value within ±5% of the higher heating value shown in Table 1 of ASHRAE 103-1993. Determine the actual higher heating value in Btu per standard cubic foot for the gas to be used in the test within an error no greater than 1%.

7.2 *Gas burner*. Adjust the burners of gas-fired furnaces to their maximum Btu input ratings at the normal test pressure specified by section 7.1 of this appendix. Correct the burner input rate to reflect gas characteristics at a temperature of 60 °F and atmospheric pressure of 30 in of Hg and adjust down to within ±2 percent of the hourly Btu nameplate input rating specified by the manufacturer as measured during the steady-state performance test in section 8 of this appendix. Set the primary air shutters in accordance with the I&O manual to give a good flame at this condition. If, however, the setting

results in the deposit of carbon on the burners during any test specified herein, the tester shall adjust the shutters and burners until no more carbon is deposited and shall perform the tests again with the new settings (*see* Figure 9 of ASHRAE 103-1993). After the steady-state performance test has been started, do not make additional adjustments to the burners during the required series of performance tests specified in section 9 of ASHRAE 103-1993. If a vent-limiting means is provided on a gas pressure regulator, keep it in place during all tests.

7.3 *Modulating gas burner adjustment at reduced input rate*. For gas-fired furnaces equipped with modulating-type controls, adjust the controls to operate the unit at the nameplate minimum input rate. If the modulating control is of a non-automatic type, adjust the control to the setting recommended in the I&O manual. In the absence of such recommendation, the midpoint setting of the non-automatic control shall be used as the setting for determining the reduced fuel input rate. Start the furnace by turning the safety control valve to the "ON" position.

7.4 *Oil burner*. Adjust the burners of oil-fired furnaces to give a CO_2 reading specified in the I&O manual and an hourly Btu input during the steady-state performance test described in section 8 of this appendix. Ensure the hourly BTU input is within ±2% of the normal hourly Btu input rating as specified in the I&O manual. Smoke in the flue may not exceed a No. 1 smoke during the steady-state performance test as measured by the procedure in ASTM D2156R13). Maintain the average draft over the fire and in the flue during the steady-state performance test at the value specified in the I&O manual. Do not allow draft fluctuations exceeding 0.005 in. water. Do not make additional adjustments to the burner during the required series of performance tests. The instruments and measuring apparatus for this test are described in section 6 of this appendix and shown in Figure 8 of ASHRAE 103-1993.

7.5 *Temperature Rise Targets*. Adjust air throughputs to achieve a temperature rise that is the higher of a and b, below, unless c applies. A tolerance of ±2 °F is permitted.

(a) 15 °F less than the nameplate maximum temperature rise or

(b) 15 °F higher than the minimum temperature rise specified in the I&O manual.

(c) A furnace with a non-adjustable air temperature rise range and an automatically controlled airflow that does not permit a temperature rise range of 30 °F or more must be tested at the midpoint of the rise range.

7.6 *Temperature Rise Adjustments*. Establish the temperature rise specified in section 7.5 of this appendix by adjusting the circulating airflow. This adjustment must be accomplished by symmetrically restricting the outlet air duct and varying blower speed selection to obtain the desired temperature rise and minimum external static pressure, as specified in Table 4 of ASHRAE 103-1993. If the required temperature rise cannot be obtained at the minimum specified external static pressure by adjusting blower speed selection and duct outlet restriction, then the following applies.

(a) If the resultant temperature rise is less than the required temperature rise, vary the blower speed by gradually adjusting the blower voltage so as to maintain the minimum external static pressure listed in Table 4 of ASHRAE 103-1993. The airflow restrictions shall then remain unchanged. If static pressure must be varied to prevent unstable blower operation, then increase the static pressure until blower operation is stabilized, except that the static pressure must not exceed the maximum external static pressure as specified by the manufacturer in the I&O manual.

(b) If the resultant temperature rise is greater than the required temperature rise, then the unit can be tested at a higher temperature rise value, but one not greater than nameplate

maximum temperature rise. In order not to exceed the maximum temperature rise, the speed of a direct-driven blower may be increased by increasing the circulating air blower motor voltage.

7.7 *Measurement of jacket surface temperature*. Divide the jacket of the furnace into 6-inch squares when practical, and otherwise into 36-square-inch regions comprising 4-inch by 9-inch or 3-inch by 12-inch sections, and determine the surface temperature at the center of each square or section with a surface thermocouple. Record the surface temperature of the 36-square-inch areas in groups where the temperature differential of the 36-square-inch areas is less than 10 °F for temperature up to 100 °F above room temperature, and less than 20 °F for temperatures more than 100 °F above room temperature. For forced-air central furnaces, the circulating air blower compartment is considered as part of the duct system, and no surface temperature measurement of the blower compartment needs to be recorded for the purpose of this test. For downflow furnaces, measure all cabinet surface temperatures of the heat exchanger and combustion section, including the bottom around the outlet duct and the burner door, using the 36-square-inch thermocouple grid. The cabinet surface temperatures around the blower section do not need to be measured (*See* Figure 3-E of ASHRAE 103-1993).

7.8 *Installation of vent system*. Keep the vent or air intake system supplied by the manufacturer in place during all tests. Test units intended for installation with a variety of vent pipe lengths with the minimum vent length as specified in the I&O manual, or a 5-ft. flue pipe if there are no recommendations in the I&O manual. Do not connect a furnace employing a direct vent system to a chimney or induced-draft source. Vent combustion products solely by using the venting incorporated in the furnace and the vent or air intake system supplied by the manufacturer. For units that are not designed to significantly preheat the incoming air, see section 7.4 of this appendix and Figure 4a or

4b of ASHRAE 103-1993. For units that do significantly preheat the incoming air, see Figure 4c or 4d of ASHRAE 103-1993.

7.9 *Additional optional method of testing for determining D_P and D_F for furnaces*. On units whose design is such that there is no measurable airflow through the combustion chamber and heat exchanger when the burner(s) is (are) off as determined by the optional test procedure in section 7.9.1 of this appendix, D_F and D_P may be set equal to 0.05.

7.9.1 *Optional test method for indicating the absence of flow through the heat exchanger*. Manufacturers may use the following test protocol to determine whether air flows through the combustion chamber and heat exchanger when the burner(s) is (are) off. The minimum default draft factor may be used only for units determined pursuant to this protocol to have no airflow through the combustion chamber and heat exchanger.

7.9.1.1 *Test apparatus*. Use a smoke stick that produces smoke that is easily visible and has a density less than or approximately equal to air. Use a smoke stick that produces smoke that is non-toxic to the test personnel and produces gas that is unreactive with the environment in the test chamber.

7.9.1.2 *Test conditions*. Minimize all air currents and drafts in the test chamber, including turning off ventilation if the test chamber is mechanically ventilated. Wait at least two minutes following the termination of the furnace on-cycle before beginning the optional test method for indicating the absence of flow through the heat exchanger.

7.9.1.3 *Location of the test apparatus*. After all air currents and drafts in the test chamber have been eliminated or minimized, position the smoke stick based on the following equipment configuration:

(a) For horizontal combustion air intakes, approximately 4 inches from the vertical plane at the termination of the intake vent and 4 inches below the bottom edge of the combustion air intake; or

(b) for vertical combustion air intakes, approximately 4 inches horizontal from vent perimeter at the termination of the intake vent and 4 inches down (parallel to the vertical axis of the vent).

7.9.1.4 *Duration of test*. Establish the presence of smoke from the smoke stick and then monitor the direction of the smoke flow for no less than 30 seconds.

7.9.1.5 *Test results*. During visual assessment, determine whether there is any draw of smoke into the combustion air intake vent.

(a) If absolutely no smoke is drawn into the combustion air intake, the furnace meets the requirements to allow use of the minimum default draft factor pursuant to section 7.9 of this appendix.

(b) If there is any smoke drawn into the intake, proceed with the methods of testing as prescribed in section 8.8 of ASHRAE 103-1993.

8. *Test procedure*. Conduct testing and measurements as specified in section 9 of ASHRAE 103-1993 (except for the excluded sub-sections as enumerated at § 430.3(g)(15)); and as specified in sections 8.1 through 8.10 of this appendix. Section 8.4 of this appendix may be used in lieu of section 9.2 of ASHRAE 103-1993.

8.1 *Fuel input*. For gas units, measure and record the steady-state gas input rate in Btu/hr, including pilot gas, corrected to standard conditions of 60 °F and 30 in. Hg. Use measured values of gas temperature and pressure at the meter and barometric pressure to

correct the metered gas flow rate to the above standard conditions. For oil units, measure and record the steady-state fuel input rate.

8.2 *Electrical input*. During the steady-state test, perform a single measurement of all of the electrical power involved in burner operation (PE), including energizing the ignition system, controls, gas valve or oil control valve, and draft inducer, if applicable.

During the steady-state test, perform a single measurement of the electrical power to the circulating air blower (BE).

8.3 *Input to interrupted ignition device*. For burners equipped with an interrupted ignition device, record the nameplate electric power used by the ignition device, PE_{IG}, or record that PE_{IG} = 0.4 kW if no nameplate power input is provided. Record the nameplate ignition device on-time interval, t_{IG}, or, if the nameplate does not provide the ignition device on-time interval, measure the on-time interval with a stopwatch at the beginning of the test, starting when the burner is turned on. Set $t_{IG} = 0$ and $PE_{IG} = 0$ if the device on-time interval is less than or equal to 5 seconds after the burner is on.

8.4 *Optional test procedures for condensing furnaces, measurement of condensate during the establishment of steady-state conditions*. For units with step-modulating or two-stage controls, conduct the test at both the maximum and reduced inputs. In lieu of collecting the condensate immediately after the steady state conditions have been reached as required by section 9.2 of ASHRAE 103-1993, condensate may be collected during the establishment of steady state conditions as defined by section 9.1.2.1 of ASHRAE 103-1993. Perform condensate collection for at least 30 minutes. Measure condensate mass immediately at the end of the collection period to prevent evaporation loss from the sample. Record fuel input for the 30-minute condensate collection test period. Observe and record fuel higher heating value (HHV), temperature, and pressures necessary for

determining fuel energy input (Qc,ss). Measure the fuel quantity and HHV with errors no greater than 1%. The humidity for the room air shall at no time exceed 80%. Determine the mass of condensate for the establishment of steady state conditions (Mc,ss) in pounds by subtracting the tare container weight from the total container and condensate weight measured at the end of the 30-minute condensate collection test period.

8.5 *Cool-down test for gas- and oil-fueled gravity and forced-air central furnaces without stack dampers*. Turn off the main burner after completing steady-state testing, and measure the flue gas temperature by means of the thermocouple grid described in section 7.6 of ASHRAE 103-1993 at 1.5 minutes ($T_{F,OFF}(t_3)$) and 9 minutes ($T_{F,OFF}(t_4)$) after shutting off the burner. When taking these temperature readings, the integral draft diverter must remain blocked and insulated, and the stack restriction must remain in place. On atmospheric systems with an integral draft diverter or draft hood and equipped with either an electromechanical inlet damper or an electromechanical flue damper that closes within 10 seconds after the burner shuts off to restrict the flow through the heat exchanger in the off-cycle, bypass or adjust the control for the electromechanical damper so that the damper remains open during the cool-down test.

For furnaces that employ post-purge, measure the length of the post-purge period with a stopwatch. Record the time from burner "OFF" to combustion blower "OFF" (electrically de-energized) as t_P. If the measured t_P is less than or equal to 30 seconds, set t_P at 0 and conduct the cool-down test as if there is no post-purge. If t_P is prescribed by the I&O manual or measured to be greater than 180 seconds, stop the combustion blower at 180 seconds and use that value for t_P. Measure the flue gas temperature by means of the thermocouple grid described in section 7.6 of ASHRAE 103-1993 at the end of the post-purge period, $t_P(T_{F,OFF}(t_P))$, and at the time $(1.5 + t_P)$ minutes ($T_{F,OFF}(t_3)$) and $(9.0 + t_P)$ minutes ($T_{F,OFF}(t_4)$) after the main burner shuts off.

8.6 *Cool-down test for gas- and oil-fueled gravity and forced-air central furnaces without stack dampers and with adjustable fan control*. For a furnace with adjustable fan control, measure the time delay between burner shutdown and blower shutdown, t^+. This time delay, t^+, will be 3.0 minutes for non-condensing furnaces or 1.5 minutes for condensing furnaces or until the supply air temperature drops to a value of 40 °F above the inlet air temperature, whichever results in the longest fan on-time. For a furnace without adjustable fan control or with the type of adjustable fan control whose range of adjustment does not allow for the time delay, t^+, specified above, bypass the fan control and manually control the fan to allow for the appropriate delay time as specified in section 9.5.1.2 of ASHRAE 103-1993. For a furnace that employs a single motor to drive both the power burner and the indoor air circulating blower, the power burner and indoor air circulating blower must be stopped at the same time

8.7 [Reserved]

8.8 *Calculation options*. The rate of the flue gas mass flow through the furnace and the factors D_P, D_F, and D_S are calculated by the equations in sections 11.6.1, 11.6.2, 11.6.3, 11.6.4, 11.7.1, and 11.7.2 of ASHRAE 103-1993. On units whose design is such that there is no measurable airflow through the combustion chamber and heat exchanger when the burner(s) is (are) off (as determined by the optional test procedure in section 7.9 of this appendix), D_F and D_P may be set equal to 0.05.

8.9 *Optional test procedures for condensing furnaces that have no off-period flue losses*. For units that have applied the test method in section 7.9 of this appendix to determine that no measurable airflow exists through the combustion chamber and heat exchanger during the burner off-period and having post-purge periods of less than 5 seconds, the cool-down and heat-up tests specified in sections 9.5 and 9.6 of ASHRAE 103-1993 may be omitted. In lieu of conducting the cool-down and heat-up tests, the tester may use the

losses determined during the steady-state test described in section 9.1 of ASHRAE 103-1993 when calculating heating seasonal efficiency, $Effy_{HS}$.

8.10 *Measurement of electrical standby and off mode power*.

8.10.1 *Standby power measurement*. With all electrical auxiliaries of the furnace not activated, measure the standby power ($P_{W,SB}$) in accordance with the procedures in IEC 62301, except that section 8.5, *Room Ambient Temperature*, of ASHRAE 103-1993 and the voltage provision of section 8.2.1.4, *Electrical Supply*, of ASHRAE 103-1993 shall apply in lieu of the corresponding provisions of IEC 62301 at section 4.2, *Test room*, and the voltage specification of section 4.3, *Power supply*. Frequency shall be 60Hz. Clarifying further, IEC 62301 section 4.4, *Power measurement instruments*, and Section 5, *Measurements,* apply in lieu of ASHRAE 103-1993 section 6.10, *Energy Flow Rate*. Measure the wattage so that all possible standby mode wattage for the entire appliance is recorded, not just the standby mode wattage of a single auxiliary. Round the recorded standby power ($P_{W,SB}$) to the second decimal place, except for loads greater than or equal to 10W, which must be recorded to at least three significant figures.

8.10.2 *Off mode power measurement*. If the unit is equipped with an off switch or there is an expected difference between off mode power and standby mode power, measure off mode power ($P_{W,OFF}$) in accordance with the standby power procedures in IEC 62301, except that section 8.5, *Room Ambient Temperature,* of ASHRAE 103-1993 and the voltage provision of section 8.2.1.4, *Electrical Supply,* of ASHRAE 103-1993 shall apply in lieu of the corresponding provisions of IEC 62301 at section 4.2, *Test room,* and the voltage specification of section 4.3, *Power supply*. Frequency shall be 60Hz. Clarifying further, IEC 62301 section 4.4, *Power measurement instruments,* and section 5, *Measurements,* apply for this measurement in lieu of ASHRAE 103-1993 section 6.10, *Energy Flow Rate*. Measure the wattage so that all possible off mode wattage for the

entire appliance is recorded, not just the off mode wattage of a single auxiliary. If there is no expected difference in off mode power and standby mode power, let $P_{W,OFF} = P_{W,SB}$, in which case no separate measurement of off mode power is necessary. Round the recorded off mode power ($P_{W,OFF}$) to the second decimal place, except for loads greater than or equal to 10W, in which case round the recorded value to at least three significant figures.

9. *Nomenclature*. Nomenclature includes the nomenclature specified in section 10 of ASHRAE 103-1993 and the following additional variables:

Eff_{motor} = Efficiency of power burner motor

PE_{IG} = Electrical power to the interrupted ignition device, kW

$R_{T,a} = R_{T,F}$ if flue gas is measured

$= R_{T,S}$ if stack gas is measured

$R_{T,F}$ = Ratio of combustion air mass flow rate to stoichiometric air mass flow rate

$R_{T,S}$ = Ratio of the sum of combustion air and relief air mass flow rate to stoichiometric air mass flow rate

t_{IG} = Electrical interrupted ignition device on-time, min.

$T_{a,SS,X} = T_{F,SS,X}$ if flue gas temperature is measured, °F

$= T_{S,SS,X}$ if stack gas temperature is measured, °F

y_{IG} = Ratio of electrical interrupted ignition device on-time to average burner on-time

y_P = Ratio of power burner combustion blower on-time to average burner on-time

E_{SO} = Average annual electric standby mode and off mode energy consumption, in kilowatt-hours

$P_{W,OFF}$ = Furnace off mode power, in watts

$P_{W,SB}$ = Furnace standby mode power, in watts

10. *Calculation of derived results from test measurements*. Perform calculations as specified in section 11 of ASHRAE 103-1993 (except for the excluded sub-sections as enumerated at § 430.3(g)(15)); and as specified in sections 10.1 through 10.11 and Figure 1 of this appendix.

10.1 *Annual fuel utilization efficiency*. The annual fuel utilization efficiency (AFUE) is as defined in sections 11.2.12 (non-condensing systems), 11.3.12 (condensing systems), 11.4.12 (non-condensing modulating systems) and 11.5.12 (condensing modulating systems) of ASHRAE 103-1993, except for the definition for the term $Effy_{HS}$ in the defining equation for AFUE. $Effy_{HS}$ is defined as:

$Effy_{HS}$ = heating seasonal efficiency as defined in sections 11.2.11 (non-condensing systems), 11.3.11 (condensing systems), 11.4.11 (non-condensing modulating systems) and 11.5.11 (condensing modulating systems) of ASHRAE 103-1993, except that for condensing modulating systems sections 11.5.11.1 and 11.5.11.2 are replaced by sections 10.2 and 10.3 of this appendix. $Effy_{HS}$ is based on the assumptions that all weatherized warm air furnaces are located outdoors and that non-weatherized warm air furnaces are installed as isolated combustion systems.

10.2 *Part-load efficiency at reduced fuel input rate*. If the option in section 8.9 of this appendix is not employed, calculate the part-load efficiency at the reduced fuel input rate,

Effy$_{U,R}$, for condensing furnaces equipped with either step-modulating or two-stage controls, expressed as a percent and defined as:

$$Effy_{U,H} = 100 - L_{L,A} + L_G - L_C - C_J L_J - \left[\frac{t_{ON}}{t_{ON} + \left(\frac{Q_P}{Q_{IN}}\right) t_{OFF}}\right](L_{S,ON} + L_{S,OFF} + L_{I,ON} + L_{I,OFF})$$

If the option in section 8.9 of this appendix is employed, calculate *Effy*$_{U,R}$ as follows:

$$Effy_{U,H} = 100 - L_{L,A} + L_G - L_C - C_J L_J - \left[\frac{t_{ON}}{t_{ON} + \left(\frac{Q_P}{Q_{IN}}\right) t_{OFF}}\right](C_S)(L_{S,SS})$$

Where:

$L_{L,A}$ = value as defined in section 11.2.7 of ASHRAE 103-1993,

L_G = value as defined in section 11.3.11.1 of ASHRAE 103-1993, at reduced input rate,

L_C = value as defined in section 11.3.11.2 of ASHRAE 103-1993 at reduced input rate,

L_J = value as defined in section 11.4.8.1.1 of ASHRAE 103-1993 at maximum input rate,

t_{ON} = value as defined in section 11.4.9.11 of ASHRAE 103-1993,

Q_P = pilot fuel input rate determined in accordance with section 9.2 of ASHRAE 103-1993 in Btu/h,

Q_{IN} = value as defined in section 11.4.8.1.1 of ASHRAE 103-1993,

t_{OFF} = value as defined in section 11.4.9.12 of ASHRAE 103-1993 at reduced input rate,

$L_{S,ON}$ = value as defined in section 11.4.10.5 of ASHRAE 103-1993 at reduced input rate,

$L_{S,OFF}$ = value as defined in section 11.4.10.6 of ASHRAE 103-1993 at reduced input rate,

$L_{I,ON}$ = value as defined in section 11.4.10.7 of ASHRAE 103-1993 at reduced input rate,

$L_{I,OFF}$ = value as defined in section 11.4.10.8 of ASHRAE 103-1993 at reduced input rate,

C_J = jacket loss factor and equal to:

= 0.0 for furnaces intended to be installed indoors

= 1.7 for furnaces intended to be installed as isolated combustion systems

= 3.3 for furnaces intended to be installed outdoors

$L_{S,SS}$ = value as defined in section 11.4.6 of ASHRAE 103-1993 at reduced input rate,

C_S = value as defined in section 11.3.10.1 of ASHRAE 103-1993 at reduced input rate.

10.3 *Part-Load Efficiency at Maximum Fuel Input Rate*. If the option in section 8.9 of this appendix is not employed, calculate the part-load efficiency at maximum fuel input rate, $Effy_{U,H}$, for condensing furnaces equipped with two-stage controls, expressed as a percent and defined as:

$$Effy_{U,R} = 100 - L_{L,A} + L_G - L_C - C_J L_J - \left[\frac{t_{ON}}{t_{ON} + \left(\frac{Q_P}{Q_{IN}}\right) t_{OFF}}\right] (L_{S,ON} + L_{S,OFF} + L_{I,ON} + L_{I,OFF})$$

If the option in section 8.9 of this appendix is employed, calculate $Effy_{U,H}$ as follows:

$$Effy_{U,R} = 100 - L_{L,A} + L_G - L_C - C_J L_J - \left[\frac{t_{ON}}{t_{ON} + \left(\frac{Q_P}{Q_{IN}}\right) t_{OFF}}\right](C_S)(L_{S,SS})$$

Where:

$L_{L,A}$ = value as defined in section 11.2.7 of ASHRAE 103-1993,

L_G = value as defined in section 11.3.11.1 of ASHRAE 103-1993 at maximum input rate,

L_C = value as defined in section 11.3.11.2 of ASHRAE 103-1993 at maximum input rate,

L_J = value as defined in section 11.4.8.1.1 of ASHRAE 103-1993 at maximum input rate,

t_{ON} = value as defined in section 11.4.9.11 of ASHRAE 103-1993,

Q_P = pilot fuel input rate determined in accordance with section 9.2 of ASHRAE 103-1993 in Btu/h,

Q_{IN} = value as defined in section 11.4.8.1.1 of ASHRAE 103-1993,

t_{OFF} = value as defined in section 11.4.9.12 of ASHRAE 103-1993 at maximum input rate,

$L_{S,ON}$ = value as defined in section 11.4.10.5 of ASHRAE 103-1993 at maximum input rate,

$L_{S,OFF}$ = value as defined in section 11.4.10.6 of ASHRAE 103-1993 at maximum input rate,

$L_{I,ON}$ = value as defined in section 11.4.10.7 of ASHRAE 103-1993 at maximum input rate,

$L_{I,OFF}$ = value as defined in section 11.4.10.8 of ASHRAE 103-1993 at maximum input rate,

C_J = value as defined in section 10.2 of this appendix,

$L_{S,SS}$ = value as defined in section 11.4.6 of ASHRAE 103-1993 at maximum input rate,

C_S = value as defined in section 11.4.10.1 of ASHRAE 103-1993 at maximum input rate.

10.4 *National average burner operating hours, average annual fuel energy consumption, and average annual auxiliary electrical energy consumption for gas or oil furnaces*.

10.4.1 *National average number of burner operating hours*. For furnaces equipped with single-stage controls, the national average number of burner operating hours is defined as:

$BOH_{SS} = 2{,}080\ (0.77)\ (A)\ DHR - 2{,}080\ (B)$

Where:

2,080 = national average heating load hours

0.77 = adjustment factor to adjust the calculated design heating requirement and heating load hours to the actual heating load experienced by the heating system

$A = 100{,}000/[341{,}200\ (y_P\ PE + y_{IG}\ PE_{IG} + y\ BE) + (Q_{IN} - Q_P)\ Effy_{HS}]$, for forced draft unit, indoors

$= 100{,}000/[341{,}200\ (y_P\ PE\ Eff_{motor} + y_{IG}\ PE_{IG} + y\ BE) + (Q_{IN} - Q_P)\ Effy_{HS}]$, for forced draft unit, isolated combustion system,

$= 100{,}000/[341{,}200\ (y_P\ PE\ (1 - Eff_{motor}) + y_{IG}\ PE_{IG} + y\ BE) + (Q_{IN} - Q_P)\ Effy_{HS}]$, for induced draft unit, indoors, and

$= 100{,}000/[341{,}200\ (y_{IG}\ PE_{IG} + y\ BE) + (Q_{IN} - Q_P)\ Effy_{HS}]$, for induced draft unit, isolated combustion system.

DHR = typical design heating requirements as listed in Table 8 (in kBtu/h) of ASHRAE 103-1993, using the proper value of Q_{OUT} defined in section 11.2.8.1 of ASHRAE 103-1993.

$B = 2\ Q_P\ (Effy_{HS})\ (A)/100{,}000$

Where:

Eff_{motor} = nameplate power burner motor efficiency provided by the manufacturer,

= 0.50, an assumed default power burner efficiency if not provided by the manufacturer.

100,000 = factor that accounts for percent and kBtu

y_P = ratio of induced or forced draft blower on-time to average burner on-time, as follows:

1 for units without post-purge;

$1 + (t_p/3.87)$ for single stage furnaces with post purge; or

$1 + (t_p/10)$ for two-stage and step modulating furnaces with post purge.

PE = all electrical power related to burner operation at full load steady-state operation, including electrical ignition device if energized, controls, gas valve or oil control valve, and draft inducer, as determined in section 8.2 of this appendix.

y_{IG} = ratio of burner interrupted ignition device on-time to average burner on-time, as follows:

0 for burners not equipped with interrupted ignition device;

(t_{IG}/3.87) for single-stage furnaces; or

(t_{IG}/10) for two-stage and step modulating furnaces;

PE_{IG} = electrical input rate to the interrupted ignition device on burner (if employed), as defined in section 8.3 of this appendix

y = ratio of blower on-time to average burner on-time, as follows:

1 for furnaces without fan delay;

$1 + (t^{+} - t^{-})/3.87$ for single-stage furnaces with fan delay; or

$1 + (t^{+} - t^{-})/10$ for two-stage and step modulating furnaces with fan delay.

BE = circulating air fan electrical energy input rate at full-load steady-state operation as defined in section 8.2 of this appendix.

t_P = post-purge time as defined in section 8.5 of this appendix

= 0 if t_P is equal to or less than 30 seconds

t_{IG} = on-time of the burner interrupted ignition device, as defined in section 8.3 of this appendix

Q_{IN} = as defined in section 11.2.8.1 of ASHRAE 103-1993

Q_P = as defined in section 11.2.11 of ASHRAE 103-1993

$Effy_{HS}$ = as defined in section 11.2.11 (non-condensing systems) or section 11.3.11.3 (condensing systems) of ASHRAE 103-1993, percent, and calculated on the basis of:

isolated combustion system installation, for non-weatherized warm air furnaces; or

outdoor installation, for furnaces that are weatherized.

2 = ratio of the average length of the heating season in hours to the average heating load hours

t^+ = delay time between burner shutoff and the blower shutoff measured as defined in section 9.5.1.2 of ASHRAE 103-1993

t^- = as defined in section 9.6.1 of ASHRAE 103-1993

10.4.1.1 For furnaces equipped with two stage or step modulating controls the average annual energy used during the heating season, E_M, is defined as:

$$E_M = (Q_{IN} - Q_P)\, BOH_{SS} + (8{,}760 - 4{,}600)\, Q_P$$

Where:

Q_{IN} = as defined in section 11.4.8.1.1 of ASHRAE 103-1993

Q_P = as defined in section 11.4.12 of ASHRAE 103-1993

BOH_{SS} = as defined in section 10.4.1 of this appendix, in which the weighted $Effy_{HS}$ as defined in section 11.4.11.3 or 11.5.11.3 of ASHRAE 103-1993 is used for calculating the values of A and B, the term DHR is based on the value of Q_{OUT} defined in section 11.4.8.1.1 or 11.5.8.1.1 of ASHRAE 103-1993, and the term ($y_PPE + y_{IG}PE_{IG} + yBE$) in the factor A is increased by the factor R, which is defined as:

R = 2.3 for two stage controls

= 2.3 for step modulating controls when the ratio of minimum-to-maximum output is greater than or equal to 0.5

= 3.0 for step modulating controls when the ratio of minimum-to-maximum output is less than 0.5

$A = 100{,}000/[341{,}200\ (y_P\ PE + y_{IG}\ PE_{IG} + y\ BE)\ R + (Q_{IN} - Q_P)\ Effy_{HS}]$, for forced draft unit, indoors

$= 100{,}000/[341{,}200\ (y_P\ PE\ Eff_{motor} + y_{IG}\ PE_{IG} + y\ BE)\ R + (Q_{IN} - Q_P)\ Effy_{HS}]$, for forced draft unit, isolated combustion system,

$= 100{,}000/[341{,}200\ (y_P\ PE\ (1 - Eff_{motor}) + y_{IG}\ PE_{IG} + y\ BE)\ R + (Q_{IN} - Q_P)\ Effy_{HS}]$, for induced draft unit, indoors, and

$= 100{,}000/[341{,}200\ (y_{IG}\ PE_{IG} + y\ BE)\ R + (Q_{IN} - Q_P)\ Effy_{HS}]$, for induced draft unit, isolated combustion system.

Where:

Eff_{motor} = nameplate power burner motor efficiency provided by the manufacturer,

= 0.50, an assumed default power burner efficiency if not provided by the manufacturer.

$Effy_{HS}$ = as defined in section 11.4.11.3 or 11.5.11.3 of ASHRAE 103-1993, and calculated on the basis of:

isolated combustion system installation, for non-weatherized warm air furnaces; or

outdoor installation, for furnaces that are weatherized.

8,760 = total number of hours per year

4,600 = as defined in section 11.4.12 of ASHRAE 103-1993

10.4.1.2 For furnaces equipped with two-stage or step-modulating controls, the national average number of burner operating hours at the reduced operating mode (BOH_R) is defined as:

$$BOH_R = X_R \, E_M / Q_{IN,R}$$

Where:

X_R = as defined in section 11.4.8.7 of ASHRAE 103-1993

E_M = as defined in section 10.4.1.1 of this appendix

$Q_{IN,R}$ = as defined in section 11.4.8.1.2 of ASHRAE 103-1993

10.4.1.3 For furnaces equipped with two-stage controls, the national average number of burner operating hours at the maximum operating mode (BOH_H) is defined as:

$$BOH_H = X_H \, E_M / Q_{IN}$$

Where:

X_H = as defined in section 11.4.8.6 of ASHRAE 103-1993

E_M = as defined in section 10.4.1.1 of this appendix

Q_{IN} = as defined in section 11.4.8.1.1 of ASHRAE 103-1993

10.4.1.4 For furnaces equipped with step-modulating controls, the national average number of burner operating hours at the modulating operating mode (BOH_M) is defined as:

$$BOH_M = X_H \, E_M / Q_{IN,M}$$

Where:

X_H = as defined in section 11.4.8.6 of ASHRAE 103-1993

E_M = as defined in section 10.4.1.1 of this appendix

$$Q_{IN,M} = Q_{OUT,M} / (Effy_{SS,M} / 100)$$

$Q_{OUT,M}$ = as defined in section 11.4.8.10 or 11.5.8.10 of ASHRAE 103-1993, as appropriate

$Effy_{SS,M}$ = as defined in section 11.4.8.8 or 11.5.8.8 of ASHRAE 103-1993, as appropriate, in percent

100 = factor that accounts for percent

10.4.2 *Average annual fuel energy consumption for gas or oil fueled furnaces*. For furnaces equipped with single-stage controls, the average annual fuel energy consumption (E_F) is expressed in Btu per year and defined as:

$$E_F = BOH_{SS} \, (Q_{IN} - Q_P) + 8{,}760 \, Q_P$$

Where:

BOH_{SS} = as defined in section 10.4.1 of this appendix

Q_{IN} = as defined in section 11.2.8.1 of ASHRAE 103-1993

Q_P = as defined in section 11.2.11 of ASHRAE 103-1993

8,760 = as defined in section 10.4.1.1 of this appendix

10.4.2.1 For furnaces equipped with either two-stage or step modulating controls, E_F is defined as:

$$E_F = E_M + 4{,}600\ Q_P$$

Where:

E_M = as defined in section 10.4.1.1 of this appendix

4,600 = as defined in section 11.4.12 of ASHRAE 103-1993

Q_P = as defined in section 11.2.11 of ASHRAE 103-1993

10.4.2.2 [Reserved]

10.4.3 *Average annual auxiliary electrical energy consumption for gas or oil-fueled furnaces*. For furnaces equipped with single-stage controls, the average annual auxiliary electrical consumption (E_{AE}) is expressed in kilowatt-hours and defined as:

$$E_{AE} = BOH_{SS}\ (y_P\ PE + y_{IG}\ PE_{IG} + yBE) + E_{SO}$$

Where:

BOH_{SS} = as defined in section 10.4.1 of this appendix

y_P = as defined in section 10.4.1 of this appendix

PE = as defined in section 10.4.1 of this appendix

y_{IG} = as defined in section 10.4.1 of this appendix

PE_{IG} = as defined in section 10.4.1 of this appendix

y = as defined in section 10.4.1 of this appendix

BE = as defined in section 10.4.1 of this appendix

E_{SO} = as defined in section 10.11 of this appendix

10.4.3.1 For furnaces equipped with two-stage controls, E_{AE} is defined as:

$$E_{AE} = BOH_R (y_P PE_R + y_{IG} PE_{IG} + yBE_R) + BOH_H (y_P PE_H + y_{IG} PE_{IG} + y BE_H) + E_{SO}$$

Where:

BOH_R = as defined in section 10.4.1.2 of this appendix

y_P = as defined in section 10.4.1 of this appendix

PE_R = as defined in section 8.2 of this appendix and measured at the reduced fuel input rate

y_{IG} = as defined in section 10.4.1 of this appendix

PE_{IG} = as defined in section 10.4.1 of this appendix

y = as defined in section 10.4.1 of this appendix

BE_R = as defined in section 8.2 of this appendix and measured at the reduced fuel input rate

BOH_H = as defined in section 10.4.1.3 of this appendix

PE_H = as defined in section 8.2 of this appendix and measured at the maximum fuel input rate

BE_H = as defined in section 8.2 of this appendix and measured at the maximum fuel input rate

E_{SO} = as defined in section 10.11 of this appendix

10.4.3.2 For furnaces equipped with step-modulating controls, E_{AE} is defined as:

$$E_{AE} = BOH_R (y_P PE_R + y_{IG} PE_{IG} + y BE_R) + BOH_M (y_P PE_H + y_{IG} PE_{IG} + y BE_H) + E_{SO}$$

Where:

BOH_R = as defined in section 10.4.1.2 of this appendix

y_P = as defined in section 10.4.1 of this appendix

PE_R = as defined in section 8.2 of this appendix and measured at the reduced fuel input rate

y_{IG} = as defined in section 10.4.1 of this appendix

PE_{IG} = as defined in section 10.4.1 of this appendix

y = as defined in section 10.4.1 of this appendix

BE_R = as defined in section 8.2 of this appendix and measured at the reduced fuel input rate

BOH_M = as defined in 10.4.1.4 of this appendix

PE_H = as defined in section 8.2 of this appendix and measured at the maximum fuel input rate

BE_H = as defined in section 8.2 of this appendix and measured at the maximum fuel input rate

E_{SO} = as defined in section 10.11 of this appendix

10.5 *Average annual electric energy consumption for electric furnaces*. For electric furnaces, the average annual electrical energy consumption (E_E) is expressed in kilowatt-hours and defined as:

$E_E = 100\ (2{,}080)\ (0.77)\ DHR/(3.412\ AFUE) + E_{SO}$

Where:

100 = to express a percent as a decimal

2,080 = as defined in section 10.4.1 of this appendix

0.77 = as defined in section 10.4.1 of this appendix

DHR = as defined in section 10.4.1 of this appendix

3.412 = conversion factor from watt-hours to Btu

AFUE = as defined in section 11.1 of ASHRAE 103-1993, in percent, and calculated on the basis of:

isolated combustion system installation, for non-weatherized warm air furnaces; or

outdoor installation, for furnaces that are weatherized.

E_{SO} = as defined in section 10.11 of this appendix.

10.6 *Energy factor*.

10.6.1 *Energy factor for gas or oil furnaces*. Calculate the energy factor, EF, for gas or oil furnaces defined as, in percent:

$EF = (E_F - 4{,}600\ (Q_P))(Effy_{HS})/(E_F + 3{,}412\ (E_{AE}))$

Where:

E_F = average annual fuel consumption as defined in section 10.4.2 of this appendix

4,600 = as defined in section 11.4.12 of ASHRAE 103-1993

Q_P = pilot fuel input rate determined in accordance with section 9.2 of ASHRAE 103-1993 in Btu/h

$Effy_{HS}$ = annual fuel utilization efficiency as defined in sections 11.2.11, 11.3.11, 11.4.11 or 11.5.11 of ASHRAE 103-1993, in percent, and calculated on the basis of:

isolated combustion system installation, for non-weatherized warm air furnaces; or

outdoor installation, for furnaces that are weatherized.

3,412 = conversion factor from kW to Btu/h

E_{AE} = as defined in section 10.4.3 of this appendix

10.6.2 *Energy factor for electric furnaces*. The energy factor, EF, for electric furnaces is defined as:

EF = AFUE

Where:

AFUE = annual fuel utilization efficiency as defined in section 10.4.3 of this appendix, in percent

10.7 *Average annual energy consumption for furnaces located in a different geographic region of the United States and in buildings with different design heating requirements*.

10.7.1 *Average annual fuel energy consumption for gas or oil-fueled furnaces located in a different geographic region of the United States and in buildings with different design heating requirements*. For gas or oil-fueled furnaces, the average annual fuel energy consumption for a specific geographic region and a specific typical design heating requirement (E_{FR}) is expressed in Btu per year and defined as:

$$E_{FR} = (E_F - 8{,}760\ Q_P)\ (HLH/2{,}080) + 8{,}760\ Q_P$$

Where:

E_F = as defined in section 10.4.2 of this appendix

8,760 = as defined in section 10.4.1.1 of this appendix

Q_P = as defined in section 11.2.11 of ASHRAE 103-1993

HLH = heating load hours for a specific geographic region determined from the heating load hour map in Figure 1 of this appendix

2,080 = as defined in section 10.4.1 of this appendix

10.7.2 *Average annual auxiliary electrical energy consumption for gas or oil-fueled furnaces located in a different geographic region of the United States and in buildings with different design heating requirements*. For gas or oil-fueled furnaces, the average

annual auxiliary electrical energy consumption for a specific geographic region and a specific typical design heating requirement (E_{AER}) is expressed in kilowatt-hours and defined as:

$E_{AER} = (E_{AE} - E_{SO})\ (HLH/2080) + E_{SOR}$

Where:

E_{AE} = as defined in section 10.4.3 of this appendix

E_{SO} = as defined in section 10.11 of this appendix

HLH = as defined in section 10.7.1 of this appendix

2,080 = as defined in section 10.4.1 of this appendix

E_{SOR} = as defined in section 10.7.3 of this appendix.

10.7.3 *Average annual electric energy consumption for electric furnaces located in a different geographic region of the United States and in buildings with different design heating requirements*. For electric furnaces, the average annual electric energy consumption for a specific geographic region and a specific typical design heating requirement (E_{ER}) is expressed in kilowatt-hours and defined as:

$E_{ER} = 100\ (0.77)\ DHR\ HLH/(3.412\ AFUE) + E_{SOR}$

Where:

100 = as defined in section 10.4.3 of this appendix

0.77 = as defined in section 10.4.1 of this appendix

DHR = as defined in section 10.4.1 of this appendix

HLH = as defined in section 10.7.1 of this appendix

3.412 = as defined in section 10.4.3 of this appendix

AFUE = as defined in section 10.4.3 of this appendix

E_{SOR} = E_{SO} as defined in section 10.11 of this appendix, except that in the equation for E_{SO}, the term BOH is multiplied by the expression (HLH/2080) to get the appropriate regional accounting of standby mode and off mode loss.

10.8 *Annual energy consumption for mobile home furnaces*

10.8.1 *National average number of burner operating hours for mobile home furnaces (BOH_{SS})*. BOH_{SS} is the same as in section 10.4.1 of this appendix, except that the value of $Effy_{HS}$ in the calculation of the burner operating hours, BOH_{SS}, is calculated on the basis of a direct vent unit with system number 9 or 10.

10.8.2 *Average annual fuel energy for mobile home furnaces (E_F)*. E_F is same as in section 10.4.2 of this appendix except that the burner operating hours, BOH_{SS}, is calculated as specified in section 10.8.1 of this appendix.

10.8.3 *Average annual auxiliary electrical energy consumption for mobile home furnaces (E_{AE})*. E_{AE} is the same as in section 10.4.3 of this appendix, except that the burner operating hours, BOH_{SS}, is calculated as specified in section 10.8.1 of this appendix.

10.9 *Calculation of sales weighted average annual energy consumption for mobile home furnaces*. To reflect the distribution of mobile homes to geographical regions with average HLH_{MHF} values different from 2,080, adjust the annual fossil fuel and auxiliary

electrical energy consumption values for mobile home furnaces using the following adjustment calculations.

10.9.1 For mobile home furnaces, the sales weighted average annual fossil fuel energy consumption is expressed in Btu per year and defined as:

$$E_{F,MHF} = (E_F - 8{,}760\ Q_P)\ HLH_{MHF}/2{,}080 + 8{,}760\ Q_P$$

Where:

E_F = as defined in section 10.8.2 of this appendix

8,760 = as defined in section 10.4.1.1 of this appendix

Q_P = as defined in section 10.2 of this appendix

HLH_{MHF} = 1880, sales weighted average heating load hours for mobile home furnaces

2,080 = as defined in section 10.4.1 of this appendix

10.9.2 For mobile home furnaces, the sales-weighted-average annual auxiliary electrical energy consumption is expressed in kilowatt-hours and defined as:

$$E_{AE,MHF} = E_{AE}\ HLH_{MHF}/2{,}080$$

Where:

E_{AE} = as defined in section 10.8.3 of this appendix

HLH_{MHF} = as defined in section 10.9.1 of this appendix

2,080 = as defined in section 10.4.1 of this appendix

10.10 [Reserved]

10.11 *Average annual electrical standby mode and off mode energy consumption*. Calculate the annual electrical standby mode and off mode energy consumption (E_{SO}) in kilowatt-hours, defined as:

$$E_{SO} = (P_{W,SB} (4160 - BOH) + 4600 P_{W,OFF}) K$$

Where:

$P_{W,SB}$ = furnace standby mode power, in watts, as measured in section 8.10.1 of this appendix

4,160 = average heating season hours per year

BOH = total burner operating hours as calculated in section 10.4 of this appendix for gas or oil-fueled furnaces. Where for gas or oil-fueled furnaces equipped with single-stage controls, $BOH = BOH_{SS}$; for gas or oil-fueled furnaces equipped with two-stage controls, $BOH = (BOH_R + BOH_H)$; and for gas or oil-fueled furnaces equipped with step-modulating controls, $BOH = (BOH_R + BOH_M)$. For electric furnaces, $BOH = 100(2080)(0.77)DHR/(E_{in}\ 3.412(AFUE))$

4,600 = as defined in section 11.4.12 of ASHRAE 103-1993

$P_{W,OFF}$ = furnace off mode power, in watts, as measured in section 8.10.2 of this appendix

K = 0.001 kWh/Wh, conversion factor from watt-hours to kilowatt-hours

Where:

100 = to express a percent as a decimal

2,080 = as defined in section 10.4.1 of this appendix

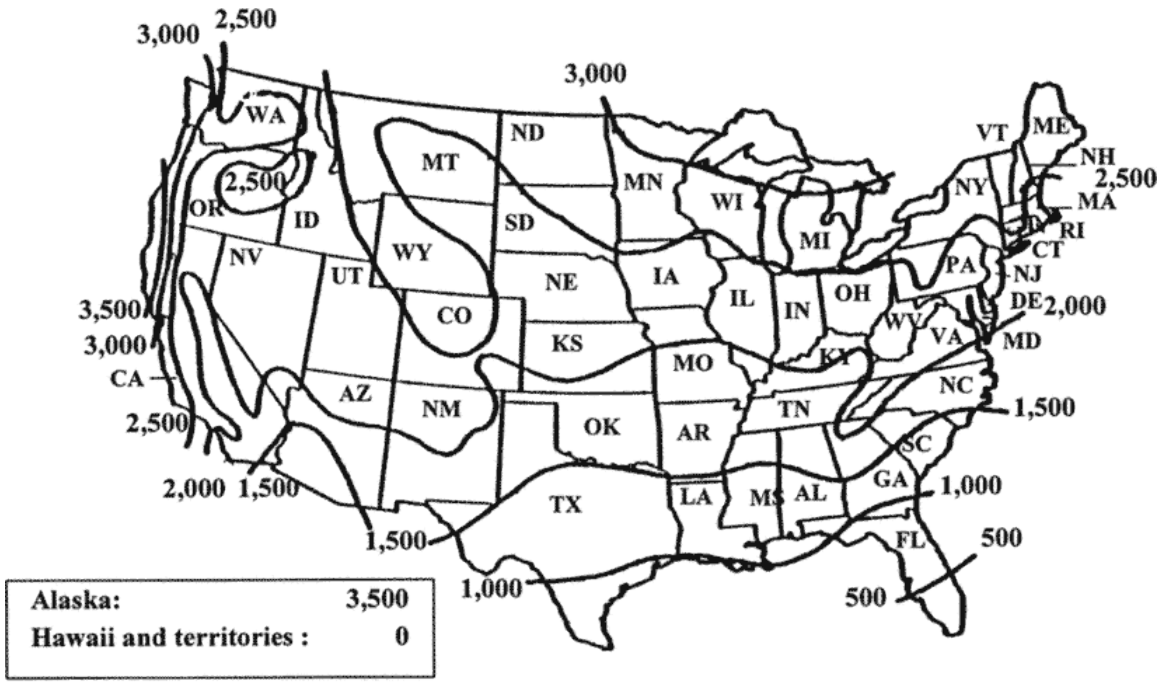
0.77 = as defined in section 10.4.1 of this appendix

DHR = as defined in section 10.4.1 of this appendix

E_{in} = steady-state electric rated power, in kilowatts, from section 9.3 of ASHRAE 103-1993

3.412 = as defined in section 10.4.3 of this appendix

AFUE = as defined in section 11.1 of ASHRAE 103-1993 in percent



This map is reasonably accurate for most parts of the United States but is necessarily generalized, and consequently not too accurate in mountainous regions, particularly in the rockies.

FIGURE 1- HEATING LOAD HOURS (HLH) FOR THE UNITED STATES

8. Appendix EE to subpart B of part 430 is added to read as follows:

Appendix EE to Subpart B of Part 430—Uniform Test Method For Measuring the Energy Consumption of Consumer Boilers

0. *Incorporation by reference*

DOE incorporated by reference in §430.3, the entire standard for ASHRAE 103-2017, ASHRAE 41.6-2014, ASTM D2156-09 (R2018), and IEC 62301. However, only enumerated provisions of ASHRAE 103-2017 are applicable to this appendix, as follows. In cases where there is a conflict, the language of the test procedure in this appendix takes precedence over the incorporated standards.

0.1 ASHRAE 103-2017

(a) Section 2 "Scope" as referenced in section 1 of this appendix;

(b) Section 3 "Definitions" as referenced in section 2 of this appendix;

(c) Section 4 "Classifications" as referenced in section 3 of this appendix;

(d) Section 5 "Requirements" as referenced in section 4 of this appendix;

(e) Section 6 "Instruments" as referenced in sections 5 and 8 of this appendix;

(f) Section 7 "Apparatus" (except for sections 7.1 and 7.8) as referenced in sections 6, 7.7, and 8.6 of this appendix;

(g) Section 8 "Methods of Testing" (except for sections 8.3.1.3, 8.3.3.1, 8.4.1.1, 8.4.1.1.1, 8.4.1.2, 8.6.1.1, 8.7.2, and 8.8.3) as referenced in sections 7 and 8 of this appendix;

(h) Section 9 "Test Procedure" (except for 9.1.2.2.1, 9.1.2.2.2, 9.5.2.1, 9.7.4, and 9.10) as referenced in sections 7.3, 8, and 10.4 of this appendix;

(i) Section 10 "Nomenclature" as referenced in section 9 of this appendix; and

(j) Section 11 “Calculations” as referenced in sections 8.8 and 10 of this appendix.

0.2 [Reserved]

1. *Scope*. The scope of this appendix is as specified in section 2 of ASHRAE 103-2017 as it pertains to low pressure steam or hot water boiler and electric boilers.

2. *Definitions*. Definitions include those specified in section 3 of ASHRAE 103-2017 and the following additional and modified definitions.

Active mode means the condition in which the boiler is connected to the power source, and at least one of the burner, electric resistance elements, or any electrical auxiliaries such as blowers or pumps, are activated.

Boiler pump means a pump installed on a boiler that maintains adequate water flow through the boiler heat exchanger and that is separate from the circulating water pump.

Draft inducer means a fan incorporated in the boiler that either draws or forces air into the combustion chamber.

Gas valve means an automatic or semi-automatic device consisting essentially of a valve and operator that controls the gas supply to the burner(s) during normal operation of an appliance. The operator may be actuated by application of gas pressure on a flexible diaphragm, by electrical means, by mechanical means or by other means.

Installation and operation (I&O) manual means instructions for installing, commissioning, and operating the boiler, which are supplied with the product when shipped by the manufacturer.

Off mode means a mode in which the boiler is connected to a mains power source and is not providing any active mode or standby mode function, and where the mode may persist for an indefinite time. The existence of an off switch in off position (a disconnected circuit) is included within the classification of off mode.

Off switch means the switch on the boiler that, when activated, results in a measurable change in energy consumption between the standby and off modes.

Oil control valve means an automatically or manually operated device consisting of an oil valve for controlling the fuel supply to a burner to regulate burner input.

Standard cubic foot of gas means the amount of gas that would occupy 1 cubic foot when at a temperature of 60 °F and under a pressure equivalent to that of 30 inches Hg if saturated with water vapor.

Standby mode means any mode in which the boiler is connected to a mains power source and offers one or more of the following space heating functions that may persist:

(a) To facilitate the activation of other modes (including activation or deactivation of active mode) by remote switch (including thermostat or remote control), internal or external sensors, or timer;

(b) Continuous functions, including information or status displays or sensor-based functions.

Thermal stack damper means a type of stack damper that relies exclusively upon the changes in temperature in the stack gases to open or close the damper.

3. *Classifications*. Classifications are as specified in section 4 of ASHRAE 103-2017.

4. *Requirements*. Requirements are as specified in section 5 of ASHRAE 103-2017.

5. *Instruments*. Instruments must be as specified in section 6 of ASHRAE 103-2017. In addition to the requirements in Section 6.3 of ASHRAE 103-2017, instruments for oil pressure shall be calibrated so that the error is no greater than ±0.5 psi.

6. *Apparatus*. The apparatus used in conjunction with the boiler during the testing must be as specified in section 7 of ASHRAE 103-2017 except for sections 7.1 and 7.8; and as specified in sections 6.1 and 6.2 of this appendix. In section 7.2.3.1 of ASHRAE 103-2017, substitute "in accordance with the I&O manual" for "in accordance with manufacturer instructions" with regard to installing the stack damper.

6.1 *General*.

(a) Install the boiler in the test room in accordance with the I&O manual, as defined in section 2.5 of this appendix, except that if provisions within this appendix are specified, then the provisions herein drafted and prescribed by DOE govern. If the I&O manual and any additional provisions of this appendix are not sufficient for testing a boiler, the manufacturer must request a waiver from the test procedure pursuant to § 430.27.

(b) The apparatuses described in section 6 of this appendix are used in conjunction with the boiler during testing. Each piece of apparatus shall conform to material and construction specifications listed in this appendix and in ASHRAE 103-2017, and the reference standards cited in this appendix and in ASHRAE 103-2017.

(c) Test rooms containing equipment must have suitable facilities for providing the utilities (including but not limited to environmental controls, sufficient fluid source(s), applicable measurement equipment, and any other technology or tools) necessary for performance of the test and must be able to maintain conditions within the limits specified in section 6 of this appendix.

6.2 *Condensate collection*. Attach condensate drain lines to the unit as specified in the I&O manual. Maintain a continuous downward slope of drain lines from the unit. Additional precautions (such as eliminating any line configuration or position that would otherwise restrict or block the flow of condensate or checking to ensure a proper connection with condensate drain spout that allows for unobstructed flow) must be taken to facilitate uninterrupted flow of condensate during the test. Collection containers must be glass or polished stainless steel to facilitate removal of interior deposits. The collection container must have a vent opening to the atmosphere.

7. *Testing conditions*. The testing conditions must be as specified in section 8 of ASHRAE 103-2017 (except for the excluded sub-sections as enumerated in section 0.1(g) of this appendix); and as specified in sections 7.1 to 7.8 of this appendix, respectively. For condensing furnaces and boilers, the relative humidity of the room air shall be measured in accordance with one of the methods described in ASHRAE 41.6-2014 (see section 8.5 of ASHRAE 103-2017).

7.1 *Fuel supply, gas*. In conducting the tests specified herein, gases with characteristics as shown in Table 1 of ASHRAE 103-2017 shall be used. Maintain the gas supply, ahead of all controls for a boiler, at a test pressure between the normal and increased values shown in Table 1 of ASHRAE 103-2017. Maintain the regulator outlet pressure at a level approximating that recommended in the I&O manual, as defined in section 2.5 of this appendix, or, in the absence of such recommendation, to the regulator settings used when the product is shipped by the manufacturer. Use a gas having a specific gravity of approximately that shown in Table 1 of ASHRAE 103-2017 and with a higher heating value within ±5% of the higher heating value shown in Table 1 of ASHRAE 103-2017.

Determine the actual higher heating value in Btu per standard cubic foot of gas (defined in section 2 of this appendix) to be used in the test within an error no greater than 1%.

7.2 *Installation of piping*. Install piping equipment in accordance with the I&O manual. In the absence of such specification, install piping in accordance with section 8.3.1.1 of ASHRAE 103-2017.

7.3 *Gas burner*. Adjust the burners of gas-fired boilers to their maximum Btu input ratings at the normal test pressure specified by section 7.1 of this appendix. Correct the burner input rate to reflect gas characteristics at a temperature of 60 °F and atmospheric pressure of 30 in of Hg and adjust to within ±2 percent of the hourly Btu nameplate input rating specified by the manufacturer as measured at the maximum input rate during the steady-state performance test in section 8 of this appendix. Set the primary air shutters in accordance with the I&O manual to give a good flame at this condition. If, however, the setting results in the deposit of carbon on the burners during any test specified herein, the tester shall adjust the shutters and burners until no more carbon is deposited and shall perform the tests again with the new settings (*see* Figure 9 of ASHRAE 103-2017). After the steady-state performance test has been started, do not make additional adjustments to the burners during the required series of performance tests specified in section 9 of ASHRAE 103-2017. If a vent-limiting means is provided on a gas pressure regulator, keep it in place during all tests.

7.4 *Modulating gas burner adjustment at reduced input rate*. For gas-fired boilers equipped with modulating-type controls, adjust the controls to operate the unit at the nameplate minimum input rate. If the modulating control is of a non-automatic type, adjust the control to the setting recommended in the I&O manual. In the absence of such recommendation, the midpoint setting of the non-automatic control shall be used as the setting for determining the reduced fuel input rate. Start the boiler by turning the safety

control valve to the "ON" position. Use a supply water temperature that will allow for continuous operation without shutoff by the control. If necessary to achieve such continuous operation, supply water may be increased above 120 °F; in such cases, gradually increase the supply water temperature to determine what minimum supply water temperature, with a 20 °F temperature rise across the boiler, will be needed to adjust for the minimum input rate at the reduced input rate control setting. Monitor regulated gas pressure out of the modulating control valve (or entering the burner) to determine when no further reduction of gas pressure results. The flow rate of water through the boiler shall be adjusted to achieve a 20 °F temperature rise.

7.5 *Oil burner*. Adjust the burners of oil-fired boilers to give a CO_2 reading specified in the I&O manual and an hourly Btu input within ±2% of the hourly Btu nameplate input rating as specified in the I&O manual and as measured at maximum input rate during steady-state performance test as described in section 8 of this appendix. Smoke in the flue may not exceed a No. 1 smoke during the steady-state performance test as measured by the procedure in ASTM D2156-09 (R2018). Maintain the average draft over the fire and in the flue during the steady-state performance test at the value specified in the I&O manual. Do not allow draft fluctuations exceeding 0.005 in. water. Do not make additional adjustments to the burner during the required series of performance tests. The instruments and measuring apparatus for this test are described in section 6 of this appendix and shown in Figure 8 of ASHRAE 103-2017.

7.6 *Measurement of jacket surface temperature*. Divide the jacket of the boiler into 6-inch squares when practical, and otherwise into 36-square-inch regions comprising 4 inch by 9 inch or 3 inch by 12 inch sections, and determine the surface temperature at the center of each square or section with a surface thermocouple. Record the surface temperature of the 36-square-inch areas in groups where the temperature differential of

the 36-square-inch areas is less than 10 °F for temperature up to 100 °F above room temperature, and less than 20 °F for temperatures more than 100 °F above room temperature.

7.7 *Installation of vent system*. Keep the vent or air intake system supplied by the manufacturer in place during all tests. Test units intended for installation with a variety of vent pipe lengths with the minimum vent length as specified in the I&O manual, or a 5-ft. flue pipe if there are no recommendations in the I&O manual. Do not connect a boiler employing a direct vent system to a chimney or induced-draft source. Vent combustion products solely by using the venting incorporated in the boiler and the vent or air intake system supplied by the manufacturer. For units that are not designed to significantly preheat the incoming air, see section 7.5 of this appendix and Figure 4a or 4b in section 7 of ASHRAE 103-2017. For units that do significantly preheat the incoming air, *see* Figure 4c or 4d in section 7 of ASHRAE 103-2017.

7.8 *Additional optional method of testing for determining D_P and D_F.* On units whose design is such that there is no measurable airflow through the combustion chamber and heat exchanger when the burner(s) is (are) off as determined by the optional test procedure in section 7.8.1 of this appendix, D_F and D_P may be set equal to 0.05.

7.8.1 *Optional test method for indicating the absence of flow through the heat exchanger*. Manufacturers may use the following test protocol to determine whether air flows through the combustion chamber and heat exchanger when the burner(s) is (are) off. The minimum default draft factor may be used only for units determined pursuant to this protocol to have no airflow through the combustion chamber and heat exchanger.

7.8.1.1 *Test apparatus*. Use a smoke stick that produces smoke that is easily visible and has a density less than or approximately equal to air. Use a smoke stick that produces

smoke that is non-toxic to the test personnel and produces gas that is unreactive with the environment in the test chamber.

7.8.1.2 *Test conditions*. Minimize all air currents and drafts in the test chamber, including turning off ventilation if the test chamber is mechanically ventilated. Wait at least two minutes following the termination of the boiler on-cycle before beginning the optional test method for indicating the absence of flow through the heat exchanger.

7.8.1.3 *Location of the test apparatus*. After all air currents and drafts in the test chamber have been eliminated or minimized, position the smoke stick based on the following equipment configuration:

(a) For horizontal combustion air intakes, approximately 4 inches from the vertical plane at the termination of the intake vent and 4 inches below the bottom edge of the combustion air intake; or

(b) for vertical combustion air intakes, approximately 4 inches horizontal from vent perimeter at the termination of the intake vent and 4 inches down (parallel to the vertical axis of the vent). In the instance where the boiler combustion air intake is closer than 4 inches to the floor, place the smoke device directly on the floor without impeding the flow of smoke.

7.8.1.4 *Duration of test*. Establish the presence of smoke from the smoke stick and then monitor the direction of the smoke flow for no less than 30 seconds.

7.8.1.5 *Test results*. During visual assessment, determine whether there is any draw of smoke into the combustion air intake vent.

If absolutely no smoke is drawn into the combustion air intake, the boiler meets the requirements to allow use of the minimum default draft factor provided in section 7.8 of this appendix.

If there is any smoke drawn into the intake, proceed with the methods of testing as prescribed in section 8.8 of ASHRAE 103-2017.

7.8.2 [Reserved]

8. *Test procedure*. Conduct testing and measurements as specified in Section 9 of ASHRAE 103-2017 (except for the excluded sub-sections as enumerated in section 0.1(h) of this appendix); and as specified in sections 8.1 through 8.9 of this appendix. Section 8.4 of this appendix may be used in lieu of section 9.2 of ASHRAE 103-2017.

8.1 *Fuel input*. For gas units, measure and record the steady-state gas input rate in Btu/h, including pilot gas, corrected to standard conditions of 60 °F and 30 in. Hg. Use measured values of gas temperature and pressure at the meter and barometric pressure to correct the metered gas flow rate to the above standard conditions. For oil units, measure and record the steady-state fuel input rate. For maximum input rate, the measured burner input rate shall be within ±2% of the hourly Btu nameplate input rating (Q_{IN}) specified by the manufacturer. For modulating furnaces and boilers operating at reduced input rate, the measured reduced heat input rate ($Q_{IN,R}$) shall be recorded. At the discretion of the one testing, the hourly Btu nameplate minimum input rating specified by the manufacturer may be used in the calculations in place of $Q_{IN,R}$ if the measured rate is within ±2% of the nameplate rating.

8.2 *Electrical input*. During the steady-state test, perform a single measurement of all of the electrical power involved in burner operation (PE), including energizing the ignition system, controls, gas valve or oil control valve, and draft inducer, if applicable. For

boilers, the measurement of PE must include the boiler pump if so equipped. If the boiler pump does not operate during the measurement of PE, add the boiler pump nameplate power to the measurement of PE. If the boiler pump nameplate power is not available, use 0.13 kW. For hot water boilers, use the circulating water pump nameplate power for BE, or if the pump nameplate power is not available, use 0.13 kW.

8.3 *Input to interrupted ignition device*. For burners equipped with an interrupted ignition device, record the nameplate electric power used by the ignition device, PE_{IG}, or record that PE_{IG} = 0.4 kW if no nameplate power input is provided. Record the nameplate ignition device on-time interval, t_{IG}, or, if the nameplate does not provide the ignition device on-time interval, measure the on-time interval with a stopwatch at the beginning of the test, starting when the burner is turned on. Set t_{IG} = 0 and PE_{IG} = 0 if the device on-time interval is less than or equal to 5 seconds after the burner is on.

8.4 *Cycling Test Requirements.* For the measurement of condensate heat loss under cyclic conditions (for condensing boilers), section 9.8 of ASHRAE 103-2017 shall apply. Cycle times calculated from Table 7 of ASHRAE 103-2017 shall be rounded to the nearest second.

8.5 *Optional test procedures for condensing boilers, measurement of condensate during the establishment of steady-state conditions*. For units with step-modulating or two-stage controls, conduct the test at both the maximum and reduced inputs. In lieu of collecting the condensate immediately after the steady state conditions have been reached as required by section 9.2 of ASHRAE 103-2017, condensate may be collected during the establishment of steady state conditions as defined by section 9.1.2.1 of ASHRAE 103-2017. Perform condensate collection for at least 30 minutes. Measure condensate mass immediately at the end of the collection period to prevent evaporation loss from the sample. Record fuel input for the 30-minute condensate collection test period. Observe

and record fuel higher heating value (HHV), temperature, and pressures necessary for determining fuel energy input ($Q_{C,SS}$). Measure the fuel quantity and HHV with errors no greater than 1%. The humidity for the room air shall at no time exceed 80%. Determine the mass of condensate for the establishment of steady state conditions ($M_{C,SS}$) in pounds by subtracting the tare container weight from the total container and condensate weight measured at the end of the 30-minute condensate collection test period.

8.6 *Cool-down test for gas- and oil-fueled boilers without stack dampers*. After steady-state testing has been completed, turn the main burner(s) "OFF" and measure the flue gas temperature at 3.75 minutes (temperature designated as $T_{F,OFF}(t_3)$) and 22.5 minutes (temperature designated as $T_{F,OFF}(t_4)$) after the burner shut-off using the thermocouple grid described in section 7.6 of ASHRAE 103-2017.

a. During this off-period, for units that do not have pump delay after shut-off, do not allow any water to circulate through the hot water boilers.

b. For units that have pump delay on shut-off, except those having pump controls sensing water temperature, the unit control must stop the pump. Measure and record the time between burner shut-off and pump shut-off (t^+) to the nearest second.

c. For units having pump delay controls that sense water temperature, operate the pump for 15 minutes and record t^+ as 15 minutes. While the pump is operating, maintain the inlet water temperature and flow rate at the same values as used during the steady-state test, as specified in sections 9.1 and 8.4.2.3 of ASHRAE 103-2017.

d. For boilers that employ post-purge, measure the length of the post-purge period with a stopwatch. Record the time from burner "OFF" to combustion blower "OFF" (electrically de-energized) as t_P. Measure the flue gas temperature by means of the thermocouple grid described in section 7.6 of ASHRAE 103-2017 at the end of the post-

purge period t_P ($T_{F,OFF}(t_P)$) and at (3.75 + t_P) minutes ($T_{F,OFF}(t_3)$) and (22.5 + t_P) minutes ($T_{F,OFF}(t_4)$) after the main burner shuts off. If t_P is prescribed by the I&O manual or measured to be greater than 3 minutes, also measure the flue gas temperature at the midpoint of the post-purge period $t_P/2$ ($T_{F,OFF}(t_P/2)$). If the measured t_P is less than or equal to 30 seconds, record t_P as 0 and conduct the cool-down test as if there is no post-purge.

8.7 [Reserved]

8.8 *Calculation options*. The rate of the flue gas mass flow through the boiler and the factors D_P, D_F, and D_S are calculated by the equations in sections 11.6.1, 11.6.2, 11.6.3, 11.6.4, 11.7.1, and 11.7.2 of ASHRAE 103-2017. On units whose design is such that there is no measurable airflow through the combustion chamber and heat exchanger when the burner(s) is (are) off (as determined by the optional test procedure in section 7.8 of this appendix), D_F and D_P may be set equal to 0.05.

8.9 *Optional test procedures for condensing boilers that have no off-period flue losses*. For units that have applied the test method in section 7.8 of this appendix to determine that no measurable airflow exists through the combustion chamber and heat exchanger during the burner off-period and having post-purge periods of less than 30 seconds, the cool-down and heat-up tests specified in sections 9.5 and 9.6 of ASHRAE 103-2017 may be omitted. In lieu of conducting the cool-down and heat-up tests, the tester may use the losses determined during the steady-state test described in section 9.1 of ASHRAE 103-2017 when calculating heating seasonal efficiency, $Effy_{HS}$.

8.10 *Measurement of electrical standby and off mode power*.

8.10.1 *Standby power measurement*. With all electrical auxiliaries of the boiler not activated, measure the standby power ($P_{W,SB}$) in accordance with the procedures in IEC

62301, except that section 8.5, *Room Ambient Temperature,* of ASHRAE 103-2017 and the voltage provision of section 8.2.1.4, *Electrical Supply,* of ASHRAE 103-2017 shall apply in lieu of the corresponding provisions of IEC 62301 at section 4.2, *Test room,* and the voltage specification of section 4.3, *Power supply*. Frequency shall be 60Hz. Clarifying further, IEC 62301 section 4.4, *Power measurement instruments,* and section 5, *Measurements,* apply in lieu of ASHRAE 103-2017 section 6.10, *Energy Flow Rate*. Measure the wattage so that all possible standby mode wattage for the entire appliance is recorded, not just the standby mode wattage of a single auxiliary. Round the recorded standby power ($P_{W,SB}$) to the second decimal place, except for loads greater than or equal to 10W, which must be recorded to at least three significant figures.

8.10.2 *Off mode power measurement*. If the unit is equipped with an off switch or there is an expected difference between off mode power and standby mode power, measure off mode power ($P_{W,OFF}$) in accordance with the standby power procedures in IEC 62301, except that section 8.5, *Room Ambient Temperature,* of ASHRAE 103-2017 and the voltage provision of section 8.2.1.4, *Electrical Supply,* of ASHRAE 103-2017 shall apply in lieu of the corresponding provisions of IEC 62301 at section 4.2, *Test room,* and the voltage specification of section 4.3, *Power supply*. Frequency shall be 60Hz. Clarifying further, IEC 62301 section 4.4, *Power measurement instruments,* and section 5, *Measurements,* apply for this measurement in lieu of SHRAE 103-2017 section 6.10, *Energy Flow Rate*. Measure the wattage so that all possible off mode wattage for the entire appliance is recorded, not just the off mode wattage of a single auxiliary. If there is no expected difference in off mode power and standby mode power, let $P_{W,OFF} = P_{W,SB}$, in which case no separate measurement of off mode power is necessary. Round the recorded off mode power ($P_{W,OFF}$) to the second decimal place, except for loads greater than or equal to 10W, in which case round the recorded value to at least three significant figures.

9. *Nomenclature*. Nomenclature includes the nomenclature specified in Section 10 of ASHRAE 103-2017 and the following additional variables:

Eff_{motor} = Efficiency of power burner motor

PE_{IG} = Electrical power to the interrupted ignition device, kW

$R_{T,a}$ = $R_{T,F}$ if flue gas is measured

= $R_{T,S}$ if stack gas is measured

$R_{T,F}$ = Ratio of combustion air mass flow rate to stoichiometric air mass flow rate

$R_{T,S}$ = Ratio of the sum of combustion air and relief air mass flow rate to stoichiometric air mass flow rate

t_{IG} = Electrical interrupted ignition device on-time, min.

$T_{a,SS,X}$ = $T_{F,SS,X}$ if flue gas temperature is measured, °F

= $T_{S,SS,X}$ if stack gas temperature is measured, °F

y_{IG} = Ratio of electrical interrupted ignition device on-time to average burner on-time

y_P = Ratio of power burner combustion blower on-time to average burner on-time

E_{SO} = Average annual electric standby mode and off mode energy consumption, in kilowatt-hours

$P_{W,OFF}$ = Boiler off mode power, in watts

$P_{W,SB}$ = Boiler standby mode power, in watts

10. *Calculation of derived results from test measurements*. Perform calculations as specified in section 11 of ASHRAE 103-2017, except for appendices B and C; and as specified in sections 10.1 through 10.7 and Figure 1 of this appendix.

10.1 *Annual fuel utilization efficiency*. The annual fuel utilization efficiency (AFUE) is as defined in sections 11.2.12 (non-condensing systems), 11.3.12 (condensing systems), 11.4.12 (non-condensing modulating systems) and 11.5.12 (condensing modulating systems) of ASHRAE 103-2017, except for the following:

10.1.1 *Off-cycle Infiltration Heat Loss.* The off-cycle infiltration heat loss ($L_{I,OFF1}$) is as defined in sections 11.2.10.8 (non-condensing systems), 11.3.10.8 (condensing systems), 11.4.10.8 (non-condensing modulating systems) and 11.5.10.8 (condensing modulating systems) of ASHREAE 103-2017, with the following exception. For systems numbered 2, 3, and 4, with a post-purge time of 3 minutes or less, $L_{I,OFF1}$ shall be determined as follows:

$$L_{I,OFF1} = 100 \times C_P \times M_{F,ON} \times t_P \times (T_{F,SS} + T_{abs}) \times \left(\frac{1}{t_{ON} \times Q_{IN}/60}\right) \times \left\{\frac{T_{IA} - T_{OA}}{C_{T,OFF} \times [T_{F,SS} - T_{F,OFF}(t_P)]} \times \ln\left[\frac{T_{RA} + T_{abs} + C_{T,OFF} \times (T_{F,SS} - T_{RA})}{T_{RA} + T_{abs} + C_{T,OFF} \times (T_{F,OFF}(t_P) - T_{RA})}\right]\right\}$$

10.1.2 *Determination of $Effy_{HS}$ in the Defining Equation for AFUE.* $Effy_{HS}$ is defined as:

$Effy_{HS}$ = heating seasonal efficiency as defined in sections 11.2.11 (non-condensing systems), 11.3.11 (condensing systems), 11.4.11 (non-condensing modulating systems) and 11.5.11 (condensing modulating systems) of ASHRAE 103-2017, and is based on the assumptions that weatherized boilers are located outdoors and that non-weatherized boilers are installed indoors.

10.1.3 *Balance Point Temperature for Condensing Modulating Boilers.* Calculate the balance point temperature (T_C) for condensing, modulating boilers by using the following equation in place of that referenced by section 11.5.8.4 of ASHRAE 103-2017: $T_C = T_{SH} - \left[(T_{SH} - T_{OA,T})(1 + \alpha)\left(\frac{Q_{IN,R}(100 - L_{L,A} - L_{S,SSR})}{Q_{IN}(100 - L_{L,A} - L_{S,SS})}\right)\right]$

Where:

T_{SH} = typical average outdoor temperature at which a boiler starts operating, 65 °F

$T_{OA,T}$ = the typical outdoor design temperature, 5 °F

α = oversize factor, as defined in 11.4.8.2

Q_{IN} = steady-state nameplate maximum fuel input rate

$Q_{IN,R}$ = steady-state reduced input fuel input rate

$L_{S,SSR}$ = average sensible heat loss at steady state, reduced input operation

$L_{S,SS}$ = average sensible heat loss at steady state, maximum input operation

10.2 *National average burner operating hours, average annual fuel energy consumption, and average annual auxiliary electrical energy consumption for gas or oil boilers*.

10.2.1 *National average number of burner operating hours*.

10.2.1.1 For boilers equipped with single-stage controls, the national average number of burner operating hours is defined as:

$BOH_{SS} = 2{,}080\ (0.77)\ (A)\ [(Q_{OUT}/1000)/(1+\alpha)] - 2{,}080\ (B)$

Where:

2,080 = national average heating load hours

0.77 = adjustment factor to adjust the calculated design heating requirement and heating load hours to the actual heating load experienced by the heating system

$A = 100{,}000/[341{,}200\ (y_P\ PE + y_{IG}\ PE_{IG} + y\ BE) + (Q_{IN} - Q_P)\ Effy_{HS}]$, for forced draft unit, indoors

$= 100{,}000/[341{,}200\ (y_P\ PE\ (1 - Eff_{motor}) + y_{IG}\ PE_{IG} + y\ BE) + (Q_{IN} - Q_P)\ Effy_{HS}]$, for induced draft unit, indoors, and

Q_{OUT} = value as defined in section 11.2.8.1 of ASHRAE 103-2017.

α = value as defined in section 11.2.8.2 of ASHRAE 103-2017.

$B = 2\ Q_P\ (Effy_{HS})\ (A)/100{,}000$

Where:

Eff_{motor} = nameplate power burner motor efficiency provided by the manufacturer,

= 0.50, an assumed default power burner efficiency if not provided by the manufacturer.

100,000 = factor that accounts for percent and kBtu

y_P = ratio of induced or forced draft blower on-time to average burner on-time, as follows:

1 for units without post-purge;

$1 + (t_P/t_{ON})$ for single stage boilers with post purge; or

PE = all electrical power related to burner operation at full load steady-state operation, including electrical ignition device if energized, controls, gas valve or oil control valve, draft inducer, and boiler pump, as determined in section 8.2 of this appendix.

y_{IG} = ratio of burner interrupted ignition device on-time to average burner on-time, as follows:

0 for burners not equipped with interrupted ignition device;

(t_{IG}/t_{ON}) for single stage boilers

PE_{IG} = electrical input rate to the interrupted ignition device on burner (if employed), as defined in section 8.3 of this appendix

y = ratio of pump on-time to average burner on-time, as follows:

1 for boilers without a pump delay;

$1 + (t^+/ t_{ON})$ for single-stage boilers with pump delay;

BE = circulating water pump electrical energy input rate at full-load steady-state operation as defined in section 8.2 of this appendix.

t_P = post-purge time as defined in section 8.5 of this appendix

= 0 if t_P is equal to or less than 30 seconds

t_{IG} = on-time of the burner interrupted ignition device, as defined in section 8.3 of this appendix

Q_{IN} = as defined in section 11.2.8.1 of ASHRAE 103-2017

Q_P = as defined in section 11.2.11 of ASHRAE 103-2017

$Effy_{HS}$ = as defined in section 11.2.11 (non-condensing systems) or section 11.3.11.3 (condensing systems) of ASHRAE 103-2017, percent, and calculated on the basis of:

indoor installation, for non-weatherized boilers; or outdoor installation, for boilers that are weatherized.

2 = ratio of the average length of the heating season in hours to the average heating load hours

t^+ = delay time between burner shutoff and the pump shutoff measured as defined in section 8.5 of this appendix.

t_{ON} = value as defined in Table 7 of ASHRAE 103-2017.

10.2.1.2 For boilers equipped with two-stage or step-modulating controls, the national average number of burner operating hours at the reduced operating mode (BOH_R) is defined as:

$$BOH_R = X_R\ (2080)(0.77)[(Q_{OUT}/1{,}000)/(1+\alpha)](A_R) - 2080(B_R)$$

Where:

X_R = as defined in section 11.4.8.6 of SHRAE 103-2017

2080 = as defined in section 10.2.1.1 of this appendix

0.77 = as defined in section 10.2.1.1 of this appendix

Q_{OUT} = as defined in section 11.4.8.1.1 or 11.5.8.1.1 of ASHRAE 103-2017

α = as defined in section 11.4.8.2 ofASHRAE 103-2017

$A_R = 100{,}000/[341{,}200(y_{P,R}PE_R + y_{IG,R}PE_{IG} + y_RBE_R) + (Q_{IN,R} - Q_P)\ Effy_{U,R}]$ for forced draft unit, indoors; and

$= 100{,}000/[341{,}200(y_{P,R}PE_R\ (1 - Eff_{motor}) + y_{IG,R}PE_{IG} + y_RBE_R) + (Q_{IN,R} - Q_P)\ Effy_{U,R}]$ for induced draft unit, indoors

$B_R = 2Q_P\ (Effy_{U,R})\ (A_R) / 100{,}000$

100,000 = conversion factor accounting for percent and 1,000 Btu/kBtu

341,200 = conversion factor accounting for percent and 3412 Btu/h/kW

$y_{P,R} = 1 + (t_p/t_{ON,R})$ for two-stage and step modulating boilers with post purge

PE_R = as defined in section 8.2 of this appendix and measured at the reduced fuel input rate

$y_{IG,R} = t_{IG}/t_{ON,R}$

PE_{IG} = as defined in section 8.3 of this appendix

$y_R = 1 + (t^+)/t_{ON,R}$ for two-stage and step modulating boilers with fan delay

BE_R = as defined in section 8.2 of this appendix and measured at the reduced fuel input rate

$Q_{IN,R}$ = as defined in section 11.4.8.1.2 of ASHRAE 103-2017

Q_P = as defined in section 11.4.12 ofASHRAE 103-2017

$Effy_{U,R}$ = as defined in section 11.4.11.1 or 11.5.11.1 of ASHRAE 103-2017, and calculated on the basis of:

indoor installation, for non-weatherized boilers; or

outdoor installation, for boilers that are weatherized.

Eff_{motor} = nameplate power burner motor efficiency provided by the manufacturer,

= 0.50, an assumed default power burner efficiency if not provided by the manufacturer.

10.2.1.3 For boilers equipped with two-stage controls, the national average number of burner operating hours at the maximum operating mode (BOH_H) is defined as:

$$BOH_H = X_H\ (2080)(0.77)[(Q_{OUT}/1{,}000)/(1+\alpha)](A_H) - 2080(B_H)$$

Where:

X_H = as defined in section 11.4.8.5 of SHRAE 103-2017

2080 = as defined in section 10.2.1.1 of this appendix

0.77 = as defined in section 10.2.1.1 of this appendix

Q_{OUT} = as defined in section 11.4.8.1.1 or 11.5.8.1.1 ofASHRAE 103-2017

α = as defined in section 11.4.8.2 of ASHRAE 103-2017

$A_H = 100{,}000/[341{,}200(y_{P,H}PE_H + y_{IG,H}PE_{IG} + y_H BE_H) + (Q_{IN,H} - Q_P)\ Effy_{U,H}]$ for forced draft unit, indoors; and

$= 100{,}000/[341{,}200(y_{P,H}PE_H\,(1 - Eff_{motor}) + y_{IG,H}PE_{IG} + y_H BE_H) + (Q_{IN,H} - Q_P)\ Effy_{U,H}]$ for induced draft unit, indoors

$B_H = 2Q_P\ (Effy_{U,H})\ (A_H) / 100{,}000$

100,000 = conversion factor accounting for percent and 1,000 Btu/kBtu

341,200 = conversion factor accounting for percent and 3412 Btu/h/kW

$y_{P,H} = 1 + (t_p/t_{ON,H})$ for two-stage and step modulating boilers with post purge

PE_H = as defined in section 8.2 of this appendix and measured at the maximum fuel input rate

$y_{IG,H} = t_{IG}/t_{ON,H}$

PE_{IG} = as defined in section 8.3 of this appendix

$y_H = 1 + (t^+)/t_{ON,H}$ for two-stage and step modulating boilers with fan delay

BE_H = as defined in section 8.2 of this appendix and measured at the maximum fuel input rate

$Q_{IN,H}$ = as defined in section 11.4.8.1.1 of ASHRAE 103-2017

Q_P = as defined in section 11.4.12 of ASHRAE 103-2017

$Effy_{U,H}$ = as defined in section 11.4.11.2 or 11.5.11.2 of ASHRAE 103-2017, and calculated on the basis of:

indoor installation, for non-weatherized boilers; or

outdoor installation, for boilers that are weatherized.

Eff_{motor} = nameplate power burner motor efficiency provided by the manufacturer,

= 0.50, an assumed default power burner efficiency if not provided by the manufacturer.

10.2.1.4 For boilers equipped with step-modulating controls, the national average number of burner operating hours at the modulating operating mode (BOH_M) is defined as:

$$BOH_M = X_H\ (2080)(0.77)[(Q_{OUT}/1{,}000)/(1+\alpha)](A_M) - 2080(B_M)$$

Where:

X_H = as defined in section 11.4.8.5 of ASHRAE 103-2017

2080 = as defined in section 10.2.1.1 of this appendix

0.77 = as defined in section 10.2.1.1 of this appendix

Q_{OUT} = as defined in section 11.4.8.1.1 or 11.5.8.1.1 of ASHRAE 103-2017

α = as defined in section 11.4.8.2 of ASHRAE 103-2017

$A_M = 100{,}000/[341{,}200(y_{P,H}PE_H + y_{IG,H}PE_{IG} + y_HBE_H) + (Q_{IN,M} - Q_P)\ Effy_{U,M}]$ for forced draft unit, indoors; and

$= 100{,}000/[341{,}200(y_{P,H}PE_H\ (1 - Eff_{motor}) + y_{IG,H}PE_{IG} + y_HBE_H) + (Q_{IN,M} - Q_P)\ Effy_{U,M}]$ for induced draft unit, indoors

$B_M = 2Q_P\ (Effy_{U,M})\ (A_M) / 100{,}000$

100,000 = conversion factor accounting for percent and 1,000 Btu/kBtu

341,200 = conversion factor accounting for percent and 3412 Btu/h/kW

$y_{P,H} = 1 + (t_p/t_{ON,H})$ for two-stage and step modulating boilers with post purge

PE_H = as defined in section 8.2 of this appendix and measured at the maximum fuel input rate

$y_{IG,H} = t_{IG}/t_{ON,H}$

PE_{IG} = as defined in section 8.3 of this appendix

$y_H = 1 + (t^+)/t_{ON,H}$ for two-stage and step modulating boilers with fan delay

BE_H = as defined in section 8.2 of this appendix and measured at the maximum fuel input rate

$Q_{IN,M} = (100)(Q_{OUT,M}/Effy_{SS,M})$

$Q_{OUT,M}$ = as defined in section 11.4.8.9 or 11.5.8.9 of ASHRAE 103-2017

$Effy_{SS,M}$ = value as defined in section 11.4.8.7 or 11.5.8.7 of ASHRAE 103-2017

Q_P = as defined in section 11.4.12 of ASHRAE 103-2017

$Effy_{U,M}$ = as defined in section 11.4.9.2.3 or 11.5.9.2.3 of ASHRAE 103-2017, and calculated on the basis of:

indoor installation, for non-weatherized boilers; or

outdoor installation, for boilers that are weatherized.

Eff_{motor} = nameplate power burner motor efficiency provided by the manufacturer,

= 0.50, an assumed default power burner efficiency if not provided by the manufacturer.

10.2.2 *Average annual fuel energy consumption for gas or oil fueled boilers*.

10.2.2.1 For boilers equipped with single-stage controls, the average annual fuel energy consumption (E_F) is expressed in Btu per year and defined as:

$$E_F = BOH_{SS} (Q_{IN} - Q_P) + 8{,}760\ Q_P$$

Where:

BOH_{SS} = as defined in section 10.2.1.1 of this appendix

Q_{IN} = as defined in section 11.2.8.1 of ASHRAE 103-2017

Q_P = as defined in section 11.2.11 of ASHRAE 103-2017

8,760 = total number of hours per year.

10.2.2.2 For boilers equipped with either two-stage or step modulating controls, E_F is defined as follows. For two-stage control:

$$E_F = (BOH_H)(Q_{IN})+(BOH_R)(Q_{IN,R})+[8760-(BOH_H+BOH_R)]Q_P$$

For step-modulating control:

$$E_F = (BOH_M)(Q_{IN,M})+(BOH_R)(Q_{IN,R})+[8760-(BOH_H+BOH_R)]Q_P$$

Where:

BOH_H = as defined in section 10.2.1.3 of this appendix

BOH_R = as defined in section 10.2.1.2 of this appendix

BOH_M = as defined in section 10.2.1.4 of this appendix

Q_{IN} = as defined in section 11.2.8.1 of ASHRAE 103-2017

$Q_{IN,R}$ = as defined in section 11.4.8.1.2 of ASHRAE 103-2017

$Q_{IN,M}$ = as defined in section 10.2.1.4 of this appendix

8,760 = total number of hours per year

Q_P = as defined in section 11.2.11 of ASHRAE 103-2017.

10.2.3 *Average annual auxiliary electrical energy consumption for gas or oil-fueled boilers*.

10.2.3.1 For boilers equipped with single-stage controls, the average annual auxiliary electrical consumption (E_{AE}) is expressed in kilowatt-hours and defined as:

$$E_{AE} = BOH_{SS} (y_P PE + y_{IG} PE_{IG} + yBE) + E_{SO}$$

Where:

BOH_{SS} = as defined in section 10.2.1.1 of this appendix

y_P = as defined in section 10.2.1.1 of this appendix

PE = as defined in section 10.2.1.1 of this appendix

y_{IG} = as defined in section 10.2.1.1 of this appendix

PE_{IG} = as defined in section 10.2.1.1 of this appendix

y = as defined in section 10.2.1.1 of this appendix

BE = as defined in section 10.2.1.1 of this appendix

E_{SO} = as defined in section 10.7 of this appendix.

10.2.3.2 For boilers equipped with two-stage controls, E_{AE} is defined as:

$$E_{AE} = BOH_R (y_{P,R} PE_R + y_{IG,R} PE_{IG} + y_R BE_R) + BOH_H (y_{P,H} PE_H + y_{IG,H} PE_{IG} + y_H BE_H) + E_{SO}$$

Where:

BOH_R = as defined in section 10.2.1.2 of this appendix

$y_{P,R}$ = as defined in section 10.2.1.2 of this appendix

PE_R = as defined in section 8.2 of this appendix and measured at the reduced fuel input rate

$y_{IG,R}$ = as defined in section 10.2.1.2 of this appendix

PE_{IG} = as defined in section 10.2.1.1 of this appendix

y_R = as defined in section 10.2.1.2 of this appendix

BE_R = as defined in section 8.2 of this appendix and measured at the reduced fuel input rate

BOH_H = as defined in section 10.2.1.3 of this appendix

PE_H = as defined in section 8.2 of this appendix and measured at the maximum fuel input rate

$y_{P,H}$ = as defined in section 10.2.1.3 of this appendix

$y_{IG,H}$ = as defined in section 10.2.1.3 of this appendix

BE_H = as defined in section 8.2 of this appendix and measured at the maximum fuel input rate

y_H = as defined in section 10.2.1.3 of this appendix

E_{SO} = as defined in section 10.7 of this appendix.

10.2.3.3 For boilers equipped with step-modulating controls, E_{AE} is defined as:

$$E_{AE} = BOH_R (y_{P,R} PE_R + y_{IG,R} PE_{IG} + y_R BE_R) + BOH_M (y_{P,H} PE_H + y_{IG,H} PE_{IG} + y_H BE_H) + E_{SO}$$

Where:

BOH_R = as defined in section 10.2.1.2 of this appendix

$y_{P,R}$ = as defined in section 10.2.1.2 of this appendix

PE_R = as defined in section 8.2 of this appendix and measured at the reduced fuel input rate

$y_{IG,R}$ = as defined in section 10.2.1.2 of this appendix

PE_{IG} = as defined in section 10.2.1 of this appendix

y_R = as defined in section 10.2.1.2 of this appendix

BE_R = as defined in section 8.2 of this appendix and measured at the reduced fuel input rate

BOH_M = as defined in 10.2.1.4 of this appendix

$y_{P,H}$ = as defined in section 10.2.1.3 of this appendix

PE_H = as defined in section 8.2 of this appendix and measured at the maximum fuel input rate

$y_{IG,H}$ = as defined in section 10.2.1.3 of this appendix

y_H = as defined in section 10.2.1.3 of this appendix

BE_H = as defined in section 8.2 of this appendix and measured at the maximum fuel input rate

E_{SO} = as defined in section 10.7 of this appendix.

10.3 *Average annual electric energy consumption for electric boilers*. For electric boilers, the average annual electrical energy consumption (E_E) is expressed in kilowatt-hours and defined as:

$$E_E = 100\ (2{,}080)\ (0.77)\ [Q_{OUT}/(1+\alpha)]/(3412\ AFUE) + E_{SO}$$

Where:

100 = to express a percent as a decimal

2,080 = as defined in section 10.2.1.1 of this appendix

0.77 = as defined in section 10.2.1.1 of this appendix

Q_{OUT} = as defined in section 11.2.8 of ASHRAE 103-2017

α = as defined in section 11.2.8.2 of ASHRAE 103-2017

3412 = conversion factor from kilowatt-hours to Btu

AFUE = as defined in section 11.1 of ASHRAE 103-2017, in percent, and calculated on the basis of:

indoor installation, for non-weatherized boilers; or

outdoor installation, for boilers that are weatherized.

E_{SO} = as defined in section 10.7 of this appendix.

10.4 *Energy factor*.

10.4.1 *Energy factor for gas or oil boilers*. Calculate the energy factor, EF, for gas or oil boilers defined as, in percent:

$$EF = (E_F - 4{,}600\ (Q_P))(Effy_{HS})/(E_F + 3{,}412\ (E_{AE}))$$

Where:

E_F = average annual fuel consumption as defined in section 10.2.2 of this appendix

4,600 = as defined in section 11.4.12 of ASHRAE 103-2017

Q_P = pilot fuel input rate determined in accordance with section 9.2 of ASHRAE 103-2017 in Btu/h

$Effy_{HS}$ = annual fuel utilization efficiency as defined in sections 11.2.11, 11.3.11, 11.4.11 or 11.5.11 of ASHRAE 103-2017, in percent, and calculated on the basis of:

indoor installation, for non-weatherized boilers; or

outdoor installation, for boilers that are weatherized.

3,412 = conversion factor from kW to Btu/h

E_{AE} = as defined in section 10.2.3 of this appendix.

10.4.2 *Energy factor for electric boilers*. The energy factor, EF, for electric boilers is defined as:

EF = AFUE

Where:

AFUE = annual fuel utilization efficiency as defined in section 10.3 of this appendix, in percent.

10.5 *Average annual energy consumption for boilers located in a different geographic region of the United States and in buildings with different design heating requirements*.

10.5.1 *Average annual fuel energy consumption for gas or oil-fueled boilers located in a different geographic region of the United States and in buildings with different design heating requirements*. For gas or oil-fueled boilers, the average annual fuel energy consumption for a specific geographic region and a specific typical design heating requirement (E_{FR}) is expressed in Btu per year and defined as:

$E_{FR} = (E_F - 8{,}760\ Q_P)\ (HLH/2{,}080) + 8{,}760\ Q_P$

Where:

E_F = as defined in section 10.2.2 of this appendix

8,760 = as defined in section 10.2.2 of this appendix

Q_P = as defined in section 11.2.11 of ASHRAE 103-2017

HLH = heating load hours for a specific geographic region determined from the heating load hour map in Figure 1 of this appendix

2,080 = as defined in section 10.2.1.1 of this appendix.

10.5.2 *Average annual auxiliary electrical energy consumption for gas or oil-fueled boilers located in a different geographic region of the United States and in buildings with different design heating requirements*. For gas or oil-fueled boilers, the average annual auxiliary electrical energy consumption for a specific geographic region and a specific typical design heating requirement (E_{AER}) is expressed in kilowatt-hours and defined as:

$$E_{AER} = (E_{AE} - E_{SO}) (HLH/2080) + E_{SOR}$$

Where:

E_{AE} = as defined in section 10.2.3 of this appendix

E_{SO} = as defined in section 10.7 of this appendix

HLH = as defined in section 10.5.1 of this appendix

2,080 = as defined in section 10.2.1.1 of this appendix

E_{SOR} = as defined in section 10.5.3 of this appendix.

10.5.3 *Average annual electric energy consumption for electric boilers located in a different geographic region of the United States and in buildings with different design heating requirements*. For electric boilers, the average annual electric energy consumption for a specific geographic region and a specific typical design heating requirement (E_{ER}) is expressed in kilowatt-hours and defined as:

$$E_{ER} = 100 (0.77) [Q_{OUT}/(1+\alpha)] HLH/(3.412 AFUE) + E_{SOR}$$

Where:

100 = as defined in section 10.2.3 of this appendix

0.77 = as defined in section 10.2.1.1 of this appendix

Q_{OUT} = as defined in section 11.2.8.1 of ASHRAE 103-2017

α = as defined in section 11.2.8.2 of ASHRAE 103-2017

HLH = as defined in section 10.5.1 of this appendix

3.412 = as defined in section 10.2.3 of this appendix

AFUE = as defined in section 10.2.3 of this appendix

E_{SOR} = E_{SO} as defined in section 10.7 of this appendix, except that in the equation for E_{SO}, the term BOH is multiplied by the expression (HLH/2080) to get the appropriate regional accounting of standby mode and off mode loss.

10.6 [Reserved]

10.7 *Average annual electrical standby mode and off mode energy consumption*. Calculate the annual electrical standby mode and off mode energy consumption (E_{SO}) in kilowatt-hours, defined as:

$$E_{SO} = (P_{W,SB} (4160 - BOH) + 4600 P_{W,OFF}) K$$

Where:

$P_{W,SB}$ = boiler standby mode power, in watts, as measured in section 8.9.1 of this appendix

4,160 = average heating season hours per year

BOH = total burner operating hours as calculated in section 10.2 of this appendix for gas or oil-fueled boilers. Where for gas or oil-fueled boilers equipped with single-stage controls, BOH = BOH_{SS}; for gas or oil-fueled boilers equipped with two-stage controls, BOH = (BOH_R + BOH_H); and for gas or oil-fueled boilers equipped with step-modulating controls, BOH = (BOH_R + BOH_M). For electric boilers, BOH = $100(2080)(0.77)[Q_{OUT}/(1+\alpha)]/(E_{in}\ 3412(AFUE))$

4,600 = as defined in section 11.4.12 of ASHRAE 103-2017

$P_{W,OFF}$ = boiler off mode power, in watts, as measured in section 8.9.2 of this appendix

K = 0.001 kWh/Wh, conversion factor from watt-hours to kilowatt-hours

Where:

100 = to express a percent as a decimal

2,080 = as defined in section 10.2.1.1 of this appendix

0.77 = as defined in section 10.2.1.1 of this appendix

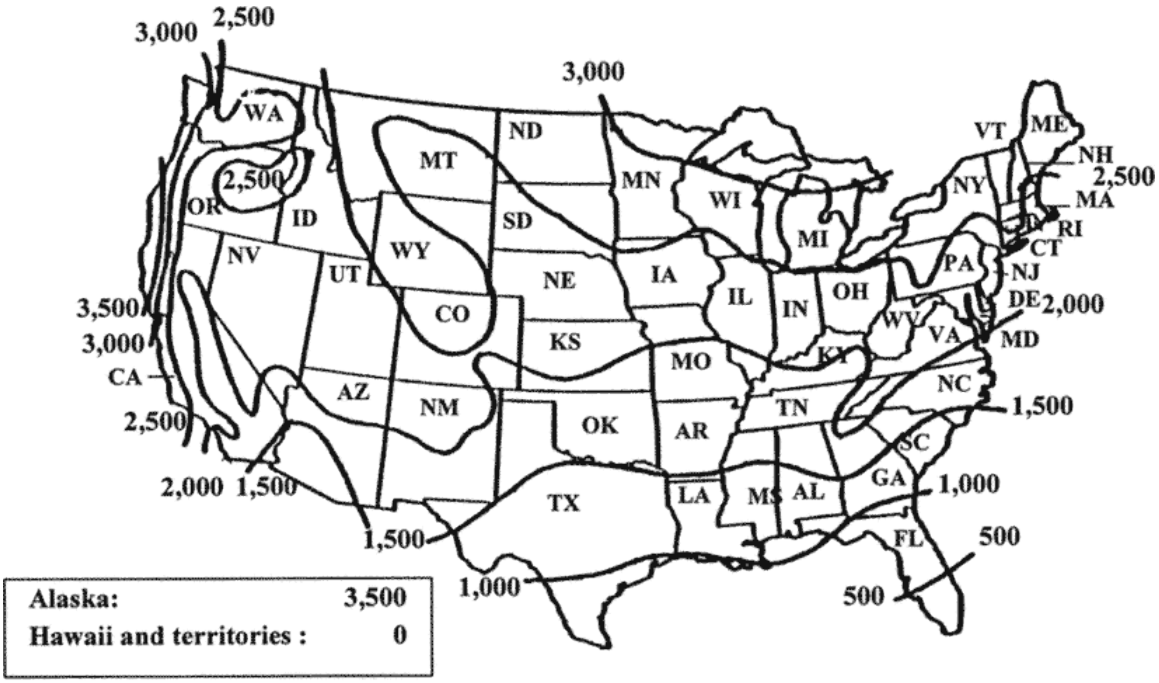
Q_{OUT} = as defined in section 11.2.8 of ASHRAE 103-2017

α = as defined in section 11.2.8.2 of ASHRAE 103-2017

E_{in} = steady-state electric rated power, in kilowatts, from section 9.3 of ASHRAE 103-2017

3412 = as defined in section 10.3 of this appendix

AFUE = as defined in section 11.1 of ASHRAE 103-2017 in percent.



This map is reasonably accurate for most parts of the United States but is necessarily generalized, and consequently not too accurate in mountainous regions, particularly in the rockies.

FIGURE 1- HEATING LOAD HOURS (HLH) FOR THE UNITED STATES

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